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Office of Air, Waste & Toxics

J.H. BAXTER & CO., a California Limited Partnership

JHBaxter

March 18, 2015

Ms. Jan Palumbo (AWT-150)
United States EPA, Region 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101

**Subject: Source Area Investigation and Chemical Oxidation Bench Study Results
J.H. BAXTER ARLINGTON FACILITY
Docket No. RCRA-10-2001-0086**

Dear Ms. Palumbo:

This letter serves as the transmittal for the Source Area Investigation and Chemical Oxidation Bench Study Results Report for the former J.H. Baxter wood treating facility located at 6520 188th Street NE in Arlington, Washington. This work was conducted under the Administrative Order on Consent (AOC) for the J.H. Baxter & Co. (Baxter) facility dated April 30, 2001.

The report provides the results of the bench scale chemical oxidation study conducted to evaluate chemical oxidation as a potential technology in areas where soils contain residual non-aqueous phase liquid (NAPL). The results were mixed. Chemical oxidation was capable of reducing the PCP concentrations; however, the amount of persulfate required (23 g/kg or 1,000,000 pounds of persulfate) was significantly higher than previously estimated (3.3 g/kg or 120,000 pounds) and this resulted in a mass removal of approximately 50%. To achieve additional removal, significant amounts of persulfate remained unused.

We look forward to discussing these results and alternatives for moving forward next Monday.

If you have any questions, please contact me at (650) 349-0201.

Sincerely,

Georgia Baxter

Georgia Baxter
Chief Executive Officer

FILE COPY

cc: Jeanne Tran, Ecology
Jamie Hillery, Stella-Jones Corp.
RueAnn Thomas, Nattura Group

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December 23, 2014

Project No. 4-61M-125612.01.2

J. H. Baxter & Co.
P.O. Box 10797
Eugene, Oregon 97440

Attention: Ms. RueAnn Thomas

Subject: Source Area Investigation and Chemical Oxidation Bench Study Results J.H. Baxter & Co., Arlington, Washington Facility

Dear Ms. Thomas:

AMEC Environment & Infrastructure, Inc. (AMEC) has prepared this Source Area Investigation and Bench Study Results, and Chemical Oxidation Pilot Test Design (Report) for the wood treating facility located at 6520 188th Street NE in Arlington, Washington ([Facility] Figure 1). Recent studies at the facility have been conducted pursuant to the Administrative Order on Consent (AOC) dated April 30, 2001.

A site plan is presented in Figure 2, and the Areas of Concern are shown on Figure 3. This Report provides additional characterization data and a pilot testing design to support in situ chemical oxidation (ISCO) as a potential technology in the area of soils containing residual non-aqueous phase liquid (NAPL) in soil (green areas in Figure 3), and natural attenuation as a potential technology in the pentachlorophenol (PCP) plume, as described in the Corrective Measures Study (CMS), Revision 3 (AMEC, 2013a). The CMS was submitted to United States Environmental Protection Agency (EPA) on April 17, 2013.

BACKGROUND AND APPROACH

The Facility is currently operated by Stella-Jones Corporation, and uses PCP as the primary wood treatment chemical. Numerous investigations and remedial activities have been completed at the facility since the 1990s. Comprehensive background information regarding the Facility's history and the nature and extent of constituents of concern (COCs) in soil and groundwater are presented in the 2005 Site Investigation (SI) Report (Baxter, 2005) and the CMS (AMEC, 2013a).

The SI and earlier investigations conducted in the 1990's identified both residual NAPL and mobile NAPL in the Main Treating Area that contributes to a PCP groundwater plume extending off-site.

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Several technologies were presented in the CMS (AMEC, 2013a) to reduce COC concentration and mass in the areas of residual and mobile NAPL in the Main Treating Area ("source areas"). Chemical oxidation was selected in the CMS as a component of the preferred alternative, pending the collection of additional facility-specific data and pilot testing.

To assess the effectiveness of the chemical oxidation technology at the Facility, a series of tasks were proposed in the Revised Source Area Investigation and Chemical Oxidation Pilot Test Work Plan (AMEC, 2013b).

The proposed tasks included the following:

- **Task 1 - Collect Source Area Soil Data.** Collect additional soil data from the NAPL-affected source area by advancing four boreholes and collection of up to six representative soil samples for laboratory analysis. The boreholes were intended to provide additional data within the source area to characterize geology, assess vertical COC distribution, and to provide material for bench studies.
- **Task 2 - Collect Source Area Groundwater Data.** Collect additional groundwater data from existing wells in and near the source areas to determine the chemical, geochemical, and biological parameters and the likelihood/potential for the use of monitored natural attenuation (MNA) or biological amendment to support plume degradation. Additional groundwater from these wells will be collected for bench studies.
- **Task 3 - Bench Testing of Source Area Soil.** Conduct bench testing of soil and groundwater material from the source areas to assess selection of oxidants and determine oxidant demand.
- **Task 4 - Evaluation of Bench Scale Data and Design of Pilot Test.** Compile and evaluate data from the supplemental soil and groundwater sampling in the source areas, as well as the bench tests. Information summarized in this evaluation will be used to design the pilot test to be implemented at the Facility, if warranted.

All work was completed in accordance with industry standard practices, and in accordance with a Facility-Specific Health and Safety Plan. Drilling, sampling, and laboratory analysis activities for both soil and groundwater were conducted in accordance with the existing Sampling Analysis Data Management Plan (SADMP) included as part of the 2002 Site Investigation Work Plan, Revision 2 (Baxter, 2002) including the collection and analysis of field duplicates and equipment rinsate blanks for quality assurance as specified in the SADMP.

TASK 1 - SOIL BORINGS IN SOURCE AREA

Four borings were completed within the source area in September 2013 (Figure 4). The borings extended to below the depth of residual NAPL, or approximately 40 feet below ground surface (bgs).

The locations of the borings represent locations with varying thickness of residual and mobile NAPL areas with wood debris, and areas with known mobile NAPL as follows:

- **Soil Boring SB-A:** This borehole is located in the northern lobe and represents an area where wood waste has been documented previously, and is adjacent to MW-12 where mobile NAPL has been historically present.
- **Soil Boring SB-B:** This borehole is located in the area with the greatest thickness of residual NAPL in the northern lobe.
- **Soil Boring SB-C:** This borehole is located in the southern lobe of residual NAPL, and, based on previous borehole logs, contains a residual NAPL over an approximate 10 foot area. This location will provide soil material that is relatively free of residual NAPL so that background oxidant demand can be calculated.
- **Soil Boring SB-D:** This borehole is located in the area with the greatest thickness of residual NAPL in the southern lobe.

Each boring in the Source Area was advanced using rotosonic drilling technology to maximize soil recovery. A soil core was retrieved from the entire length of each boring, and inspected by a geologist for soil types, lithology, obvious signs of contamination (using visual, olfactory, and vapor monitoring methods), presence/absence of water or NAPL, and presence of debris or non-soil matter (Baxter, 2002 - SADMP Section B2). Representative grab samples were obtained from the soil borings and retained for laboratory analysis and bench testing as summarized on Table 1a. A flow chart illustrating the decision process for selection of soil samples for laboratory analysis and bench testing is provided as Figure 5.

FIELD OBSERVATIONS

Boring logs are presented in Attachment A. The boring logs and analytical results reveal the following about the putative source areas:

1. Soil types encountered include aggregate gravel base near the surface, near surface wood debris at SB-A and SB-B, and fine to coarse sand and gravel at depth.
2. Vadose zone soils were moist in all four boreholes. Saturated conditions (wet) were observed at depths between 29.5 feet bgs and 33 feet bgs.
3. At SB-A and SB-B, odor and volatiles are first detected in the wood debris starting at 6 and 3.5 feet bgs, respectively, and in sand at 3.5 feet bgs in SB-C. Odor and volatiles were first observed in SB-D in sand at a depth of 26.5 feet bgs.

4. Free NAPL and/or NAPL droplets were visible in the soil described as wet in each boring. A sheen and/or NAPL droplets was observed at shallower locations in the vadose zone at each location.

ANALYTICAL RESULTS

The soil analysis results for PCP, total petroleum hydrocarbons (TPH) as diesel range organics (DRO) or residual range organics (RRO), and geochemical and biological parameters are presented in Table 2, and soil metals in Table 3. The laboratory reports are in Attachment B. Analytical results are summarized below, and explained in detail later in this document.

1. The petroleum hydrocarbon chromatograms appear to represent a heavily degraded product, missing the alkanes and other low molecular weight constituents typically found in a diesel or fuel oil.
2. The soils within SB-A were sampled and analyzed at four discrete depth intervals. Diesel and residual organic component concentrations increased with depth to 30 to 33 feet bgs, then decreased at 40 to 41 feet bgs. Pentachlorophenol concentrations were highest at 24 to 27 feet bgs.
3. Within SB-C soil at 30 to 33 feet bgs petroleum hydrocarbons are present at low concentrations, but PCP is present at an elevated concentration.
4. At SB-D, petroleum hydrocarbons are present in soil at an elevated concentration at 30 to 33 feet bgs. Pentachlorophenol was detected at 530,000 micrograms per kilogram (µg/kg) at 30 to 33 feet bgs, the highest level observed during this investigation.
5. Data from the boreholes indicate that the soil is deficient in the levels of the nutrients nitrogen and phosphorus needed to degrade the total organic carbon present (when compared to a generic nutrient demand of 100 parts carbon to 10 parts nitrogen to 1 part phosphorus).
6. Petroleum hydrocarbon degrading bacteria are largely absent from the soil examined.
7. Desulfitobacterium species are present at elevated populations in the soils at 24 to 27 feet bgs at SB-A.
8. The PCP regulator gene expression is high in the soils at SB-A, and at SB-D.
9. The PCP-4-monoxygenase gene expression is elevated at 16 to19 feet bgs in SB-A, and at 30 to 33 feet bgs at SB-D.

The presence of microbial species known to degrade PCP, and of bacterial genes indicating microbial populations having PCP degradation enzyme pathways, are further discussed below in the section titled Interpretation of CENSUS Results for Soil and Groundwater.

TASK 2 - GROUNDWATER MONITORING FOR CONSTITUENT FATE ASSESSMENT

Groundwater at five existing Facility wells were sampled for analysis of a variety of chemical, geochemical, and biological parameters (Table 1b). The well locations were selected to obtain data from upgradient of the plume, from within and near the source area, and from downgradient plume locations to provide information regarding the chemical, geochemical, and biological changes in groundwater quality along the plume vector. All sample collection and laboratory analysis was conducted in accordance with the SADMP (Baxter, 2002 - Section B2 and B3) using submersible pumps and appropriate water quality monitoring equipment. Purge water from the sampling activities was containerized, and then recycled in the existing remediation system.

Groundwater samples were collected from five locations as follows (Figure 6):

- MW-11 (upgradient well)
- MW-12 (source area well)
- MW-32 (near-source area well)
- MW-36 (mid-plume well)
- MW-41 (downgradient plume well)

Microbial Insights (Knoxville, Tennessee) provided Bio-Trap® samplers used to collect microbes in the groundwater at monitoring wells MW-12, MW-36, and MW-41. The Bio-Trap® samplers were hung from tethers within the groundwater column of each monitoring well on September 19, 2013, and were retrieved from the wells on December 2, 2013. The Bio-Trap® sampling matrix, Bio-Sep® beads, are 2 to 4 millimeters (mm) in diameter and are an engineered composite of Nomex® and powdered activated carbon (PAC). When a Bio-Trap® sampler is deployed in a monitoring well, the Bio-Sep® beads absorb contaminants and nutrients present in the aquifer essentially becoming an in situ microcosm with an incredibly large surface area (approximately 600 cubic milligrams per gram [m^2/g]) which is readily colonized by subsurface microorganisms. Microbial Insights extracts deoxyribonucleic acid (DNA) from the beads for CENSUS® assays to evaluate the microbial community, and data is reported as cells per bead.

The key analytical results and field parameters for the groundwater samples are summarized on Table 4. Chlorophenol, metals, and dissolved gas results are reported on Table 5.

The groundwater analysis indicates the following:

1. Upgradient conditions (MW-11) are oxic, and the groundwater is deficient in the levels of the nutrients nitrogen and phosphorus needed to degrade the total organic carbon present (when

compared to a generic nutrient demand of 100 parts carbon to 10 parts nitrogen to 1 part phosphorus).

2. Source area conditions (MW-12) are anoxic, poised at a redox potential that supports iron reduction to ferrous iron, but not sulfate reduction to sulfide. Tetrachlorophenol and 2,4,5-trichlorophenol are present at relatively low concentrations, likely a sign of dechlorination occurring in the source area. Bacteria that degrade diesel-range hydrocarbons are not detected. The genes indicative of the anaerobic bacteria known to reductively degrade PCP (Dehalococcoides, and Desulfitobacterium spp.) are not detected, which is not surprising given these bacteria require more strongly anaerobic conditions than occur in the groundwater. The PCP regulator gene is present, and the two other genes associated with oxidative degradation of PCP (Maleylacetate Reductase and PCP-4-Monooxygenase) are present, showing that the site groundwater may be able to support aerobic degradation of PCP.

3. The petroleum hydrocarbon chromatogram for the groundwater sample from MW-12 appears to represent a heavily degraded product, missing many of the alkanes and other low molecular weight constituents typically found in a diesel or fuel oil.

4. Just downgradient of the source area (MW-32) conditions appear to be less reducing, as evidenced by elevated ORP and lack of ferrous iron. Bacteria that degrade diesel-range hydrocarbons are clearly present, and diesel concentrations in groundwater are clearly diminished. Chloride is elevated, possibly a sign of PCP degradation.

5. Down plume conditions (MW-36 and MW-41) are increasingly oxidizing (as measured by ORP). Bacteria that degrade diesel-range hydrocarbons are not present, probably due to the low levels of diesel available in the groundwater at these locations. Chloride is elevated, possibly a sign of PCP degradation. The PCP-related aerobic biodegradation genes are present at elevated levels, and there is a decrease in groundwater PCP concentration between MW-36 and MW-41, consistent with active aerobic biodegradation of PCP.

Overall, the bacteria with the capability to biodegrade diesel range hydrocarbons are present in the area just downgradient of the plume, and bacteria with the genetic markers appropriate for aerobic PCP degradation are more concentrated at downgradient plume locations. The decrease in PCP concentrations in groundwater between MW-36 and MW-41 provides additional evidence for active aerobic biodegradation of PCP.

INTERPRETATION OF CENSUS RESULTS FOR SOIL AND GROUNDWATER

The presence of specific microbial genetic material can serve as a marker for potential biological activity. The CENSUS analysis for this project involved assessing the presence of DNA indicators of aerobic biodegradation enzyme genes (genes for PCP regulator, PCP-4-monooxygenase and maleylacetate reductase), and genomes of known anaerobic or anoxic PCP biodegraders (Dehalococoicides, and Desulfitobacterium spp.). Microbial Insights suggests that 10,000 to 100,000 cells/bead in groundwater, or cells per gram in soil would be a mid-range concentration of cells with the genetic potential to support PCP biodegradation, and that less than 1,000 cells/ per bead or gram of soil would be in the lower range of concentration.

INDICATORS OF AEROBIC BIODEGRADATION POTENTIAL

Under aerobic conditions, some bacteria can utilize PCP as a sole source of carbon and energy (Cai and Xun 2002). Typically, the PCP regulator gene (pcpR) controls the expression of genes encoding for the enzymes PCP-4-monooxygenase (pcpB) and maleylacetate reductase (pcpE), among others. Research has shown that genes which encode for the above mentioned enzymes are expressed in the presence of PCP. These genes are more fully activated under aerobic conditions, but it has been shown that aerobic oxygenase genes can retain some activity under low oxygen conditions, poised to respond rapidly to any influx in oxygen.

The initial step in PCP biodegradation under aerobic conditions involves actions mediated by PCP-4-monooxygenase, followed by a later step involving the maleylacetate reductase gene (Cai and Xun 2002). The literature suggests that the rate-limiting step in aerobic PCP biodegradation occurs when PCP-4-monooxygenase enzyme oxidizes PCP to form 2,3,5,6-tetrachlorohydroquinone.

The PCP regulator, PCP-4-monooxygenase and maleylacetate reductase genes are detected in each groundwater sample tested. The highest levels of PCP regulator gene occurred at MW-12 (30,500 cells per bead) in the source area, whereas the highest levels of the PCP-4-monooxygenase and maleylacetate reductase genes were detected at MW-36, farther downgradient in the more aerobic area of the plume.

In soil, the PCP regulator gene is present at a higher range (as high as 1.24E07 cells per gram in vadose zone soil at SB-A: 16-19, and 1.61E06 cells per gram in saturated soil at SB-D: 30-33) in each sample tested. The PCP-4-monooxygenase gene is detected in soils SB-A: 16-19 and SB-D: 30-33. The maleylacetate reductase genes were not detected in soil.

INDICATORS OF ANAEROBIC BIODEGRADATION POTENTIAL

In the soil samples, the Desulfitobacterium are present at levels of up to 6.98E06 in soil at SB-A, but are not detected in the soil sample from SB-D: 30-33, or in any of the groundwater samples (Tables 2 and 4). The Dehalococoicides were not detected in either the soil or the groundwater samples tested.

Strains of the anaerobes Desulfitobacterium are capable of reductive dechlorination of PCP and other chlorinated phenols, using the chlorophenols as electron acceptors (Villemur 2013).

Desulfitobacterium strain PCP-1 is known to dechlorinate PCP to 3-chlorophenol but other Desulfitobacterium species are only capable of ortho-dechlorination (Villemur 2013).

The Desulfitobacterium values decrease with depth in the soil column at SB-A. The samples with the highest values are in unsaturated soils containing product sheen and droplets (see intervals SB-A: 16-19 and SB-A: 24-27 in boring log in Attachment A). The sample collected at SB-A: 30-33 was from below the water table, and free product is visible, but the bacterial values are lower here. Groundwater at nearby monitoring well MW-12 is only slightly anaerobic (sulfate is present, see Table 4), suggesting that conditions within the groundwater are not optimally anaerobic for the Desulfitobacterium growth. However, the groundwater at MW-12 does contain low levels of tetrachlorophenols and 2,4,5-trichlorophenol, suggesting that some reductive dechlorination of PCP may be occurring (Table 5).

TASK 3 - BENCH STUDY FOR IN SITU CHEMICAL OXIDATION

As discussed in the CMS (AMEC, 2013), Chemical Oxidation and Enhanced Biodegradation Recirculation was selected as a component of the preferred alternative, subject to additional characterization and pilot testing. The oxidants persulfate and permanganate were assessed in a bench study of site soil and groundwater completed by Ursus Remediation Testing & Technologies, LLC (Ursus) of Mt. Horeb, Wisconsin. The bench study assessed the total oxidant demand (TOD), the effectiveness of site soil and groundwater treatment with persulfate and permanganate, and dosing guidance for in situ applications. The details of the bench testing program are presented in the Ursus report (2014) (see Attachment C).

Six soil samples were collected during Task 1, and were then submitted to Ursus (Table 6). Soil samples were collected in wide mouth glass soil jars with no headspace. Approximately 5 liters of groundwater was collected from monitoring well MW-12 in wide mouth glass bottles with no headspace. All samples were placed in coolers with ice, and handled under chain of custody in accordance with the SADMP (Section B3).

Total Oxidant Demand Testing

Each of the six soil samples underwent TOD testing. Groundwater from monitoring well MW-12 was used in the making of test slurries with each of the soil samples. The TOD testing entailed addition of either alkaline activated sodium persulfate, or sodium permanganate to the soil slurry at three dosages. Then, residual oxidant measurements were made on the slurries approximately 48 and 96 hours post treatment. Subtraction of the residual oxidant concentration from the known starting oxidant concentration yields TOD. TOD results show that SB-A: 10-11 and SB-C: 20-21 had the greatest persulfate TOD (greater than 10.0 g/kg) while the other samples showed lesser TOD – ranging from 0.9 to 4.5 g/kg at 96 hours. Each of the samples had a permanganate TOD greater than

10 g/kg at 96 hours. TOD testing showed all of the permanganate was utilized within 96 hours. Persulfate testing showed either all persulfate was utilized or an increasing demand from 48 to 96 hours. Both cases suggest the oxidant demand was not met for all samples.

The TOD testing suggested that oxidant demand was higher than initial estimates. Therefore, to better estimate the oxidant demand, a persulfate stoichiometric calculation was performed prior to the effectiveness testing using the diesel-range organic (DRO), residual-range organic (RRO), and PCP concentrations known for the soil samples. An initial assumption was made that the DRO, RRO, and PCP would be equally susceptible to oxidation, and that achieving 50% degradation of PCP would be adequate to affirm oxidant feasibility. On this basis, the stoichiometric demand was initially estimated at 350 grams of sodium persulfate per kilogram of soil SB-A: 24-27, and 92 g of sodium persulfate per kilogram of soil SB-D: 30-33.

EFFECTIVENESS TESTING – 1ST ROUND FROM NOVEMBER 18, 2013 TO FEBRUARY 28, 2014

Following TOD analysis, two soil samples, SB-A: 24-27 (representing highly PCP-affected unsaturated soil) and SB-D: 30-33 (representing highly PCP-affected saturated soil) were selected for effectiveness testing. Information from TOD testing, and estimates of the expected oxidant demand due to the diesel mass present were used to set the dosage levels for effectiveness testing.

Soil/groundwater slurry samples were treated under four conditions:

1. base activated sodium persulfate
2. iron activated sodium persulfate
3. hydrogen peroxide activated sodium persulfate
4. sodium permanganate

Multiple oxidant applications were applied over a 78 day period to meet the estimated stoichiometric oxidant demand. The testing design is discussed in detail in Ursus 2014. Summaries of the date are presented in Tables 7 and 8.

Control and treated samples were allowed to react for 102 days. Ursus measured secondary parameters in the liquid phase of treatment samples, including residual persulfate or permanganate, and pH, at days 22, 49, 78 and 102. Selected metals (arsenic, chromium, copper, lead) were measured in the liquid phase of treatment samples on days 49 and 102. Reactor sets underwent total extraction on day 49 and on day 102, and the total mass of PCP and DRO present in soil and water was analyzed from the extract.

Results of 1st Round of Effectiveness Testing

Reduction of PCP concentrations in treated samples in comparison to controls was observed under all chemistry conditions by day 49 during Round 1 testing. Significant lowering of PCP concentration (in excess of 90%) was observed with all activated persulfate chemistries and with permanganate in the sample SB-A: 24-27. Alkaline persulfate doses of 46 mg/kg and 92 mg/kg were present in sample SB-A: 24-27. In sample SB-D: 30-33, alkaline persulfate doses of 87.5 mg/kg and 175 mg/kg removed approximately 97% of the PCP, with other treatment chemistries removing between 21% and 75% of the PCP.

No significant reduction in DRO concentration was observed in the treated samples. Residual oxidant remained at elevated levels in the treated samples.

Treatment by alkaline persulfate did appear to make the metals arsenic and total chromium more available to extraction, whereas, copper and lead availability remained largely unchanged. Under the other test conditions, chromium and copper availability increased, whereas arsenic and lead availability remained largely unchanged.

Thus, the major conclusions of Round 1 of effectiveness testing are:

1. The PCP is more susceptible to oxidation than the DRO.
2. High rates of PCP removal are more readily achieved with alkaline persulfate treatment than with other treatment chemistries.
3. Residual oxidant remained at elevated levels in the treated samples, indicating that an excess of oxidant was used, and that lower oxidant doses could be used, thus improving treatment cost effectiveness.

Round 1 testing showed alkaline activated persulfate to be more effective in reducing PCP concentrations than peroxide activated persulfate, iron activated persulfate, or permanganate. Round 1 testing found alkaline activated persulfate significantly reduced PCP concentrations within 49 days, using a persulfate dose as low as 46 g/kg.

As discussed earlier, a main assumption had been that DRO, RRO, and PCP would be equally susceptible to oxidation, thus leading to a high estimated stoichiometric oxidant demand. Round 1 of effectiveness testing showed that PCP under alkaline conditions is more susceptible to oxidation than the DRO, and that much lower oxidant doses than those initially tested in Round 1 would likely bring about a 50% reduction in PCP concentration. Thus a second round of effectiveness testing was proposed using lower doses of alkaline persulfate.

EFFECTIVENESS TESTING – 2ND ROUND FROM JUNE 26 TO AUGUST 14, 2014

The goals of Round 2 testing were:

1. To establish whether doses of alkaline persulfate lower than 46 g/kg would remove significant amounts of PCP.
2. To establish whether less waste of persulfate would occur, as evidenced by lower residual oxidant values.

Round 2 testing was conducted with alkaline activated persulfate at doses of 8 g/kg, 16 g/kg, and 23 g/kg, which were allowed to react for 49 days in samples SB-A: 24-27 and SB-D: 30-33. During Round 2, the PCP concentration was lowered between 42% and 57% in treated samples of SB-A: 24-27. The persulfate doses of 8 g/kg, 16 g/kg, and 23 g/kg performed to nearly equal extents at removing PCP from sample SB-A: 24-27. The PCP concentration was lowered between 0% and 69% in treated samples of SB-D: 30-33. The persulfate dose of 23 g/kg removed between 55% and 69% of the PCP from sample SB-A: 24-27. Only low reductions in DRO concentrations was observed in either SB-A: 24-27 or SB-D: 30-33 at the dosages tested in Round 2. Summaries of the date are presented in Tables 7 and 8, and on Figure 7.

Round 2 testing found alkaline activated persulfate significantly reduced PCP concentrations within 49 days at a dose of 23 g/kg in both samples SB-A: 24-27 and SB-D: 30-33, and at doses lower than 23 g/kg in sample SB-A: 24-27 (Figure 7). Little or no residual oxidant remained at the end of the Round 2 tests, indicating efficient usage of the persulfate (Figure 7).

The bench effectiveness testing establishes that significant removal of PCP can occur at a concentration of alkaline activated persulfate of 23 g/kg, or lower in some cases. Less wasted, unused persulfate remains at the end of 49 days when using the 23 g/kg dose than when using higher persulfate doses. A persulfate concentration of 23 g/kg should be used in designing, and estimating costs for a pilot study.

DEVIATIONS FROM THE WORK PLAN

The following deviations from the ISCO bench test portion of the Revised Source Area Investigation and Chemical Oxidation Pilot Test Work Plan (AMEC 2013b) are noted:

- Page 7 of the work plan suggested that the water fraction would be separated from the soil fraction and the respective fractions will be analyzed. During the bench study, the soil and groundwater slurry underwent total extraction, and the total PCP and TPH-D in the reactors was measured.

- Page 7 of the work plan suggested that soil and groundwater samples and/or data would be provided to vendors for independent assessment (i.e., Regenesis, FMC/Adventus) (see page 7 of the work plan). The soil and groundwater samples and/or data have not yet been shared with vendors.

CONCLUSIONS

AMEC advanced exploratory soil borings in the source area; collected soil and groundwater samples for chemical, geochemical, and biological evaluation; and designed and implemented bench treatability studies to assess the feasibility of soil and groundwater treatment by in situ chemical oxidation.

- The exploratory soil borings indicate elevated levels of PCP, and the widespread presence of highly weathered petroleum hydrocarbons.
- The soil contains microorganisms that appear to be suitable for biodegradation of PCP, petroleum hydrocarbon degrading bacteria are largely absent, and nutrient levels do not appear adequate to support petroleum hydrocarbon biodegradation.
- The groundwater in the source area is anoxic, but not strongly anaerobic. Bacteria that degrade diesel-range hydrocarbons, and genes indicative of the anaerobic bacteria known to reductively degrade PCP (Dehalococcoides, and Desulfitobacterium spp.) are not detected, although low levels of PCP reductive dechlorination products are detected. The genes indicative of aerobic PCP-degrading microorganisms are present.
- The groundwater at mid plume location MW-32 is more aerobic, and contains petroleum hydrocarbon degrading bacteria. The groundwater at down plume locations MW-36 and MW-41 is relatively aerobic, the PCP-related aerobic biodegradation genes are present, and there is a decrease in PCP concentrations in groundwater between MW-36 and MW-41. Thus, use of enhanced natural attenuation of PCP represents a possible effective remedial alternative.
- The bench testing demonstrates that alkaline persulfate is a more effective oxidant system for PCP removal from soil and groundwater in the source area. The bench testing results also indicate that PCP is oxidized preferentially over the petroleum hydrocarbons under the alkaline conditions tested.
- The bench effectiveness testing establishes that significant removal of PCP can occur at an alkaline activated persulfate concentration of 23 g/kg, or lower in some cases. Thus, a persulfate concentration of 23 g/kg should be used in designing, and estimating costs for, a pilot study.

LIMITATIONS

This report was prepared exclusively for J.H. Baxter & Co. by AMEC Environment & Infrastructure, Inc. The quality of information, conclusions, and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this report. This Source Investigation and Chemical Oxidation Bench Study Results is intended to be used by J.H. Baxter & Co. for Arlington, Washington Facility only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

If you have any additional questions or comments, please do not hesitate to contact Steve Barnett at (503) 639-3400.

AMEC Environment & Infrastructure, Inc.	**Reviewed By:**
Jack Spadaro, PhD, CHMM Associate Scientist	J. Stephen Barnett, LG Senior Associate

Attachments: Table 1a – Soil Sample Laboratory Method Summary
Table 1b – Groundwater Sample Laboratory Method Summary
Table 2 – Soil Chemical, Geochemical, and Biological Data Summary
Table 3 – Soil Metals Results
Table 4 – Groundwater Chemical, Geochemical, and Biological Data Summary
Table 5 - Groundwater Chlorophenol, Metals, and Dissolved Gas Data
Table 6 – Soil Samples Submitted for Oxidant Bench Testing
Table 7 – Summary of Bench Oxidation Effectiveness Testing at Day 49
Table 8 – Summary of All Bench Oxidation Effectiveness Testing Data

Figure 1 – Site Vicinity Map
Figure 2 – Site Plan and Groundwater Monitoring Network
Figure 3 – Areas of Concern
Figure 4 – Borehole Soil Sampling Locations and Results – September 2013
Figure 5 – Soil Sampling Guide
Figure 6 – Summary of Groundwater PCP, DRO and Biological Monitoring Results – September / December 2013
Figure 7 – Pentachlorophenol Oxidized and Persulfate Residual at Day 49

Attachment A – Boring Logs
Attachment B – Soil and Groundwater Laboratory Analytical Reports
Attachment C – Ursus Bench Treatability Study Report

SB/lp

c: Georgia Baxter, J.H. Baxter & Co.

REFERENCES

Baxter, 2002. Site Investigation Work Plan, Revision 2. J.H. Baxter & Co. Wood Treating Facility, Arlington, Washington. Prepared for EPA Region 10 by the J.H. Baxter Project Team. May 15.

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TABLES

TABLES 1a AND 1b
Soil and Groundwater Sample Laboratory Method Summary
Former J.H. Baxter Co. Wood Treating Facility
Arlington, Washington

Table 1a
Soil Sample Laboratory Method Summary

				Method	8151M	NWTPH-DX	353.2	9056	6010B	2320B	ASTM D4129	4500NH3E	365.3	9045	160.3	ASTM D422	HDB	CENSUS	Ursus Bench	Ursus Bench
Station ID	**Sample ID**	**Sample Date**	**Sample Type**	**Matrix**	**Penta-chloro-phenol**	**Diesel and Residual Oil**	**Nitrate/ Nitrite**	**Sulfate/ Chloride**	**Metals**	**Total Alkalinity**	**Total Organic Carbon**	**Ammonia as Nitrogen**	**Ortho-phosphate**	**pH**	**Total Solids, Percent Solids**	**Grain Size**	**Hydro-carbon Degrading Bacteria**	**DNA / RNA**	**Total Oxidant Demand**	**ISCO Effectiveness Test**
SB-A	SB-A:10-11	9/21/2013	N	SO															X	
SB-A	SB-A:16-19	9/21/2013	N	SO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
SB-A	SB-A:24-27	9/21/2013	N	SO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SB-A	SB-A:30-33	9/21/2013	N	SO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
SB-A	SB-A:40-41	9/21/2013	N	SO	X	X	X	X	X	X	X	X	X	X	X	X	X			
SB-A	SB-E:30-33	9/21/2013	FD	SO	X	X									X					
SB-C	SB-C:20-21	9/21/2013	N	SO															X	
SB-C	SB-C:30-33	9/21/2013	N	SO	X	X	X	X	X	X	X	X	X	X	X	X	X			
SB-D	SB-D:30-33	9/21/2013	N	SO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 1b
Groundwater Sample Laboratory Method Summary

				Method	8151M	NWTPH-DX	300	6010B	9030	RSK 175	2320B	415.1	4500NH3E	4500PE	FIELD PARAM	HDB	CENSUS	Ursus Bench	Ursus Bench
Location	**Sample ID**	**Sample Date**	**Sample Type**	**Matrix**	**Chlorinated Phenols**	**Diesel and Residual Oil**	**Nitrate/ Nitrite/ Sulfate**	**Metals**	**Total Sulfide**	**Methane/ Ethane/ Ethene**	**Total Alkalinity**	**Total Organic Carbon**	**Ammonia as Nitrogen**	**Ortho-phosphate**	**Field**	**Hydro-carbon Degrading Bacteria**	**DNA / RNA**	**Total Oxidant Demand**	**ISCO Effectiveness Test**
MW-11	MW-11_20130919	9/19/2013	N	GW	X	X	X	X	X	X	X	X	X	X	X	X			
MW-12	MW-12_20130921	9/21/2013	N	GW	X	X	X	X	X	X	X	X	X	X	X	X		X	X
MW-32	MW-32_20130919	9/19/2013	N	GW	X	X	X	X	X	X	X	X	X	X	X	X			
MW-32	MW-44_20130919	9/19/2013	FD	GW	X	X	X	X	X	X	X	X	X	X		X			
MW-36	MW-36_20130919	9/19/2013	N	GW	X	X	X	X	X	X	X	X	X	X	X	X			
MW-41	MW-41_20130919	9/19/2013	N	GW	X	X	X	X	X	X	X	X	X	X	X	X			
MW-45	MW-45_20130919	9/19/2013	EB	GW	X	X	X	X	X	X	X	X	X	X		X			
MW-12	MW-12-BT	12/2/2013	N	BT													X		
MW-36	MW-36-BT	12/2/2013	N	BT													X		
MW-41	MW-41-BT	12/2/2013	N	BT													X		

Notes:
BT = Biotrap placed within groundwater well
EB = Equipment blank
FD = Field duplicate
GW = Groundwater
ISCO = In situ chemical oxidation
N = Normal samples
SO = Soil

TABLE 2
Soil Chemical, Geochemical, and Biological Data Summary
Former J.H. Baxter Co. Wood Treating Facility
Arlington, Washington

Station ID	Sample ID	Sample Date	Depth (ft bgs)	Pentachlorophenol (PCP)	TPH as Diesel	Residual Range Organics	Nitrate	Nitrate+Nitrite as Nitrogen	Nitrite	Manganese	Iron	Sulfate	Total Alkalinity	Chloride	Hydrocarbon Degrading Bacteria	Dehalococcoides	Desulfitobacterium spp.	Maleylacetate Reductase	PCP Regulator Gene	PCP-4-Monooxygenase	Total Organic Carbon	Ammonia as Nitrogen	Orthophosphate	pH	Total Solids
				µg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	MPN/g	cells/g	cells/g	cells/g	cells/g	cells/g	percent	mg/kg	mg/kg	pH units	percent
SB-A	SB-A:16-19	9/21/2013	16-19	**1,100**	**3,000**	**170**	0.52 U	**0.17 J**	**0.12 J**	**229**	**17,100**	3.7 U	**83.0**	3.7 U	9.4 U	1,000 U	**6,980,000**	2,000 U	**12,400,000**	**640,000**	**0.274**	**1.41**	**0.34**	**7.17**	**95.7**
SB-A	SB-A:24-27	9/21/2013	24-27	**110,000**	**13,000**	**660**	**0.10 J**	**0.18 J**	**0.08 J**	**255**	**21,100**	**1.3 J**	**80.1**	**1.8 J**	9.6 U	1,000 U	**3,640,000**	2,000 U	**144,000**	2000 U	**0.533**	**0.56**	**0.20**	**7.09**	**94.1**
SB-A	SB-A:30-33	9/21/2013	30-33	**15,000**	**22,000**	**1,200 J**	**0.27 J**	**0.33 J**	**0.06 J**	**241**	**21,300**	**2.4 J**	**626**	**1.3 J**	10 U	1,000 U	**250**	2,000 U	**327,000**	2000 U	**0.946**	**2.01**	**0.19**	**6.94**	**87.7**
SB-A	SB-A:40-41	9/21/2013	40-41	**1,600**	**7.5 J**	**10 J**	**0.12 J**	**0.15 J**	**0.03 J**	**305**	**22,600**	**2.3 J**	**530**	**1.4 J**	**12**	NT	NT	NT	NT	NT	**0.099**	**1.64**	**0.69**	**7.06**	**77.7**
SB-C	SB-C:30-33	9/21/2013	30-33	**3,000**	**220**	**38 J**	**0.11 J**	**0.11 J**	0.29 U	**325**	**21,200**	**5.6**	**601**	**9.5**	10 U	NT	NT	NT	NT	NT	**0.162**	**1.02**	**0.91**	**7.24**	**87.2**
SB-D	SB-D:30-33	9/21/2013	30-33	**530,000**	**20,000**	**1,500**	**0.10 J**	**0.14 J**	**0.04 J**	**264**	**20,100**	**3.7 J**	**201**	5.3 U	12 U	1,000 U	2,000 U	2,000 U	**1,610,000**	**78,400**	**0.982**	**0.40**	**0.15**	**6.87**	**73.1**

Notes:
BOLD = detection
Results not validated
cells/g = cells per gram
NT = not tested
mg/kg = milligrams per kilogram
MPN/g = most probable number of cells per gram
pH units = standard unit
µg/kg = micrograms per kilogram
Data reported to reporting detection limit
U = not detected at or above the stated level
J = estimated result

TABLE 3
Soil Metals Results
Former J.H. Baxter Co. Wood Treating Facility
Arlington, Washington

Station ID	Sample ID	Sample Date	Depth (ft bgs)	Aluminum	Calcium	Iron	Magnesium	Manganese
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
SB-A	SB-A:16-19	9/21/2013	16-19	**10,900**	**3,130**	**17,100**	**7,690**	**229**
SB-A	SB-A:24-27	9/21/2013	24-27	**12,600**	**3,120**	**21,100**	**10,600**	**255**
SB-A	SB-A:30-33	9/21/2013	30-33	**13,900**	**2,620**	**21,300**	**9,220**	**241**
SB-A	SB-A:40-41	9/21/2013	40-41	**14,900**	**3,180**	**22,600**	**9,200**	**305**
SB-C	SB-C:30-33	9/21/2013	30-33	**13,000**	**2,960**	**21,200**	**8,480**	**325**
SB-D	SB-D:30-33	9/21/2013	30-33	**13,000**	**2,420**	**20,100**	**8,810**	**264**

Notes:
BOLD = detection
Results not validated
ft bgs = feet below ground surface
mg/kg = milligrams per kilogram
Data reported to reporting detection limit
U = not detected at or above the stated level
J = estimated result

TABLE 4
Groundwater Chemical, Geochemical, and Biological Data Summary
Former J.H. Baxter Co. Wood Treating Facility
Arlington, Washington

Well	Sample ID	Sample Date	Sample Type	Pentachlorophenol	TPH as Diesel	Residual Range Organics	Oxygen Reduction Potential	Dissolved Oxygen	Nitrate	Nitrite	Manganese	Iron	Ferrous Iron	Sulfate	Total Sulfide	Methane	Total Alkalinity	Chloride	Hydrocarbon Degrading Bacteria	Dehalococcoides	Desulfitobacterium spp.	PCP Regulator Gene	Maleylacetate Reductase	PCP-4-Monooxygenase	Total Organic Carbon	Ammonia as Nitrogen	Orthophosphate	Groundwater Temperature	pH	Specific Conductivity
				µg/L	µg/L	µg/L	mV	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	MPN/ 100mL	cells/ bead	cells/ bead	cells/ bead	cells/ bead	cells/ bead	mg/L	mg/L	mg/L	deg C	pH units	ms/cm
MW-11	MW-11_20130919	9/19/2013	N	0.50 U	260 U	520 U	**255.7**	**3.15**	**0.21**	0.10 U	**5.3**	**136**	0.0 U	**4.35**	0.10 U	**1.3**	**73.7**	**2.64**	900 U	NT	NT	NT	NT	NT	**1.12**	**0.035 J**	0.050 U	**12.8**	**6.32**	**0.155**
MW-12	MW-12_20130921	9/21/2013	N	**360**	**82,000**	**4,100**	**-33.0**	**0.71**	0.10 U	0.10 U	**1,720**	**2,920**	**3.0**	**7.35**	0.10 U	**28**	**89.4**	**2.97**	900 U	25 U	250 U	**30,500**	**1,870**	**795**	**3.46**	**0.152**	0.050 U	**12.8**	**5.66**	**0.200**
MW-32	MW-32_20130919	9/19/2013	N	**640**	**390**	**37 J**	**200.4**	**0.35**	**0.36**	**0.03 J**	**25.0**	**913**	0.0 U	**8.53**	0.10 U	**1.3**	**56.2**	**6.54**	**13,500**	NT	NT	NT	NT	NT	**1.41**	**0.044 J**	0.050 U	**11.6**	**5.87**	**0.147**
MW-32	MW-44_20130919	9/19/2013	FD	**730**	**390**	**33 J**	NT	NT	**0.37**	**0.03 J**	**9.0**	**235**	NT	**8.60**	0.10 U	**1.3**	**56.3**	**6.62**	**3,900**	NT	NT	NT	NT	NT	**1.35**	**0.037 J**	0.050 U	NT	NT	NT
MW-36	MW-36_20130919	9/19/2013	N	**1,300**	**79 J**	520 U	**212.9**	**0.24**	**0.12**	0.10 U	**626**	20.0 U	NT	**12.1**	0.10 U	**1.3**	**143**	**8.12**	900 U	25 U	250 U	**16,400**	**7,710**	**6,440**	**2.38**	**0.013 J**	0.050 U	**12.0**	**6.23**	**0.314**
MW-41	MW-41_20130919	9/19/2013	N	**370**	**200 J**	**28 J**	**245.0**	**0.18**	**0.14**	0.10 U	**68.9**	20.0 U	0.0 U	**14.2**	0.10 U	**15**	**65.2**	**7.01**	900 U	25 U	250 U	**14,600**	**3,070**	**1,890**	**1.53**	**0.036 J**	0.050 U	**11.6**	**5.78**	**0.173**
MW-45	MW-45_20130919	9/19/2013	EB	**0.93**	260 U	520 U	NT	NT	0.10 U	0.10 U	**0.10 J**	20.0 U	NT	0.20 U	0.10 U	**1.3**	**3.2**	0.40 U	**2,000**	NT	NT	NT	NT	NT	0.50 U	**0.100**	0.050 U	NT	NT	NT

Notes:
BOLD = detection
Results not validated
Data reported to reporting detection limit
cells/bead = cells per bead
deg C = celsius
EB = equipment blank
FD = field duplicate
mg/L = milligrams per liter
MPN/100 mL = Most probable number of cells per 100 mL of solution
ms/cm = milli-Siemens per centimeter
N = Normal sample
NT = Not tested
µg/L = micrograms per liter
U = not detected at or above the stated level
J = estimated result

TABLE 5
Groundwater Chlorophenol, Metals, and Dissolved Gas Data
Former J.H. Baxter Co. Wood Treating Facility
Arlington, Washington

Well	Sample ID	Sample Date	Pentachlorophenol	Tetrachlorophenols, Total	2,4,5-Trichlorophenol	2,4,6-Trichlorophenol	3,4-Dichlorophenol	3,5-Dichlorophenol	Aluminum	Calcium	Iron	Magnesium	Manganese	Ethane	Ethene	Methane
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
MW-11	MW-11_20130919	9/19/2013	0.50 U	1.0 U	1.0 U	0.50 U	2.0 U	2.0 U	**86.7**	**13,600**	**136**	**7,080**	**5.3**	**0.60**	**1.0**	**1.3**
MW-12	MW-12_20130921	9/21/2013	**360**	**12**	**0.34 J**	0.50 U	2.0 U	2.0 U	**30.9**	**20,900**	**2,920**	**6,330**	**1,720**	**0.60**	**1.0**	**28**
MW-32	MW-32_20130919	9/19/2013	**640**	38 U	1.0 U	0.50 U	2.0 U	2.0 U	**579**	**11,000**	**913**	**7,650**	**25.0**	**0.60**	**1.0**	**1.3**
MW-32	MW-44_20130919	9/19/2013	**730**	1.5 U	1.0 U	0.50 U	2.0 U	2.0 U	**158**	**11,300**	**235**	**7,620**	**9.0**	**0.60**	**1.0**	**1.3**
MW-36	MW-36_20130919	9/19/2013	**1300**	1.0 U	1.0 U	0.50 U	2.0 U	2.0 U	10.0 U	**26,700**	20.0 U	**19,000**	**626**	**0.60**	**1.0**	**1.3**
MW-41	MW-41_20130919	9/19/2013	**370**	9.7 U	1.0 U	0.50 U	2.0 U	2.0 U	10.0 U	**13,100**	20.0 U	**9,380**	**68.9**	**0.60**	**1.0**	**15**
MW-45	MW-45_20130919	9/19/2013	**0.93**	1.0 U	1.0 U	0.50 U	2.0 U	2.0 U	10.0 U	**82.3**	20.0 U	**2.2 J**	**0.10 J**	**0.60**	**1.0**	**1.3**

Notes:
BOLD = detection
Results not validated
µg/L = micrograms per liter
Data reported to reporting detection limit
U = not detected at or above the stated level
J = estimated result

TABLE 6
Soil Samples Submitted for Oxidant Bench Testing
Former J.H. Baxter Wood Treating Facility,
Arlington, Washington

Sample ID	Sample Type	Zone at Time of Drilling	Diesel Range Organics (mg/kg)	Residual Range Organics (mg/kg)	Penta-chlorophenol (µg/kg)
SB-A: 10-11	Woody Debris w/ Sand	Vadose	NA	NA	NA
SB-A: 16-19	Sand w/ Gravel	Vadose	**3,000**	**170**	**1,100**
SB-C: 20-21	Sand w/ Gravel	Vadose	NA	NA	NA
SB-A: 24-27	Sand w/ Gravel	Vadose	**13,000**	**660**	**110,000**
SB-A: 30-33	Sand w/ Silt & Gravel	Saturated	**22,000**	**1,200 J**	**15,000**
SB-D: 30-33	Sand w/ Silt	Saturated	**20,000**	**1,500**	**530,000**

Notes:
BOLD = detection
Results not validated
NA = not applicable
mg/kg = milligrams per kilogram
µg/kg = micrograms per kilogram
Data reported to reporting detection limit
U = not detected at or above the stated level
J = estimated result

TABLE 7
Summary of Bench Oxidation Effectiveness Testing at Day 49
Former J.H. Baxter and Co. Wood Treating Facility
Arlington, Washington

Sample SB-A: 24-27	Persulfate Concentration	Diesel (g/kg)	Fraction Decrease in Diesel	PCP (mg/kg)	Fraction PCP Decrease	Average Fraction PCP Decrease	Persulfate Remaining (g/kg)
2nd Round: 26Jun2014 through 14Aug2014	2nd Rd CONTROL (0 g/kg)	10,000	-	19	-	-	-
	2nd Rd CONTROL Dup (0 g/kg)	NT	-	9.9	-	-	-
	8 g/kg	9,800	0.02	7.4	0.49	0.48	1.2
	8 g/kg Duplicate	NT	-	7.5	0.48	-	-
	16 g/kg	8,900	0.11	6.2	0.57	0.50	2.2
	16 g/kg Duplicate	NT	-	8.2	0.43	-	-
	23 g/kg	11,000	-0.10	8.4	0.42	0.44	3.2
	23 g/kg Duplicate	NT	-	7.7	0.47	-	-
1st Round: 18Nov2013 through 28Feb2014	1st Rd CONTROL (0 g/kg)	7,200	-	45	-	-	-
	87.5 g/kg	9,200	-0.28	3.6	0.98	0.98	29.9
	175 g/kg	11,000	-0.53	2.2	0.99	0.99	38.1

Sample SB-D: 30-33	Persulfate Concentration	Diesel (g/kg)	Fraction Decrease in Diesel	PCP (mg/kg)	Fraction PCP Decrease	Average Fraction PCP Decrease	Persulfate Remaining (g/kg)
2nd Round: 26Jun2014 through 14Aug2014	2nd Rd CONTROL (0 g/kg)	12,000	-	18	-	-	-
	2nd Rd CONTROL Dup (0 g/kg)	NT	-	22	-	-	-
	8 g/kg	14,000	-0.17	26	-0.30	-0.30	ND
	8 g/kg Duplicate	NT	-	26	-0.30	-	-
	16 g/kg	14,000	-0.17	20	0.00	0.35	1
	16 g/kg Duplicate	NT	-	6.2	0.69	-	-
	23 g/kg	15,000	-0.25	9	0.55	0.62	2.2
	23 g/kg Duplicate	NT	-	6.3	0.69	-	-
1st Round: 18Nov2013 through 28Feb2014	1st Rd CONTROL (0 g/kg)	12,000	-	190	-	-	-
	46 g/kg	11,000	0.08	5.8	0.97	0.97	6.8
	92 g/kg	8,000	0.00	4.8	0.97	0.97	36.1

Notes:

All data shown is from Day 49 of the experiment
g/kg = grams persulfate per kilogram of soil
mg/kg = milligrams per kilogram
NT = not tested
PCP = Pentachlorophenol
\- = not applicable

TABLE 8
Summary of All Bench Oxidation Effectiveness Testing Data
Former J.H. Baxter and Co. Wood Treating Facility
Arlington, Washington

Sample ID	Day 22				Day 49											
	Persulfate Dosage g/kg	pH, s.u.	TOD g/kg	Residual Oxidant g/kg	Persulfate Dosage g/kg	pH s.u.	TOD g/kg	Residual Oxidant g/kg	As mg/L	Cr (total) mg/L	Cu mg/L	Pb mg/L	DRO mg/kg	DRO % Reduction	PCP mg/kg	PCP % Reduction
Round 2 (26Jun2014 through 14Aug2014)																
SB-D-30-33 - Control	0	NT	NT	NT	0.0	NT	NT	NT	NT	NT	NT	NT	12,000	-	18	-
	0 (Dup)	NT	NT	NT	0.0	NT	NT	NT	NT	NT	NT	NT	NT	-	22	-
SB-D-30-33 - Alk Pers	8.0	NT	NT	NT	8	10.3	> 8	ND	NT	NT	NT	NT	14,000	-17%	26	-30%
	8.0 (Dup)	NT	NT	NT	8	NT	NT	NT	NT	NT	NT	NT	NT	-	26	-30%
	16.0	NT	NT	NT	16	10.02	15	1	NT	NT	NT	NT	14,000	-17%	20	0%
	16.0 (Dup)	NT	NT	NT	16	NT	NT	NT	NT	NT	NT	NT	NT	-	6.2	69%
	23.0	NT	NT	NT	23	10.11	20.8	2.2	NT	NT	NT	NT	15,000	-25%	9	55%
	23.0 (Dup)	NT	NT	NT	23	NT	NT	NT	NT	NT	NT	NT	NT	-	6.3	69%
SB-A-24-27 - Control	0	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	10,000	-	19	-
	0 (Dup)	NT	NT	NT	DUP	NT	NT	NT	NT	NT	NT	NT	NT	-	9.9	-
SB-A-24-27 - Alk Pers	8.0	NT	NT	NT	8	9.28	6.8	1.2	NT	NT	NT	NT	9,800	2%	7.4	49%
	8.0 (Dup)	NT	NT	NT	8 DUP	NT	NT	NT	NT	NT	NT	NT	NT	-	7.5	48%
	16.0	NT	NT	NT	16	9.34	13.8	2.2	NT	NT	NT	NT	8,900	11%	6.2	57%
	16.0 (Dup)	NT	NT	NT	16 DUP	NT	NT	NT	NT	NT	NT	NT	NT	-	8.2	43%
	23.0	NT	NT	NT	23	9.59	19.8	3.2	NT	NT	NT	NT	11,000	-10%	8.4	42%
	23.0 (Dup)	NT	NT	NT	23 DUP	NT	NT	NT	NT	NT	NT	NT	NT	-	7.7	47%
Round 1 (18Nov2013 through 28Feb2014)																
SB-D-30-33 - Control	0	NT	NT	NT	NT	NT	NT	NT	<0.30	<0.050	<0.050	<0.30	12,000	-	190	-
SB-D-30-33 - Alk Pers	23.0	10.30	19.9	3.1	46.0	12.19	39.2	6.8	0.94	0.92	0.060	<0.30	11,000	8%	5.8	97%
	46.0	13.49	35.6	10.4	92.0	12.75	55.9	36.1	1.14	1.94	0.073	<0.30	12,000	0%	4.8	97%
SB-D-30-33 - H2O2/Pers	23.0	3.50	19.1	3.9	46.0	2.45	37.9	8.1	<0.30	0.36	1.44	<0.30	11,000	8%	110	42%
	46.0	2.70	26.7	19.3	92.0	2.18	50.7	41.3	<0.30	1.07	2.92	<0.30	8,600	28%	150	21%
SB-D-30-33 - Fe Pers	23.0	2.66	19.2	3.8	46.0	2.40	38.1	7.9	<0.30	0.34	1.60	<0.30	13,000	-8%	80	58%
	46.0	2.42	26.4	19.6	92.0	2.18	51.7	40.3	<0.30	0.66	2.52	0.31	8,000	33%	48	75%
SB-D-30-33 - Na Perm	23.0	NT	6.6	16.4	23.0	NT	11.5	11.5	<3.0	3.50	1.14	<3.0	15,000	-25%	58	69%
SB-A-24-27 - Control	0	NT	NT	NT	NT	NT	NT	NT	<0.30	<0.050	0.10	<0.30	7,200	-	45	-
SB-A-24-27 - Alk Pers	43.8	11.59	36.6	7.1	87.5	12.69	57.6	29.9	1.43	2.96	0.061	<0.30	9,200	-28%	3.6	98%
	87.5	11.16	77.7	9.8	175	12.82	137	38.1	1.48	3.12	0.064	0.31	11,000	-53%	2.2	99%
SB-A-24-27 - H2O2 Pers	43.8	3.45	27.5	16.3	87.5	2.07	49.8	37.7	<0.30	1.32	3.03	0.033	7,600	-6%	14	93%
	87.5	2.68	68.0	19.5	175	1.87	135	40.0	<0.30	2.21	3.81	0.45	6,200	14%	12	94%
SB-A-24-27 - Fe Pers	43.8	2.72	27.5	16.2	87.5	2.03	48.0	39.5	<0.30	1.31	2.89	<0.30	6,100	15%	11	94%
	87.5	2.56	68.4	19.1	175	1.94	134	41.1	<0.30	1.29	2.94	<0.30	6,100	15%	13	93%
SB-A-24-27 - Na Perm	43.8	NT	31.3	12.5	43.8	NT	41.3	2.5	<3.0	13.2	1.08	<3.0	7,200	0%	4.8	97%

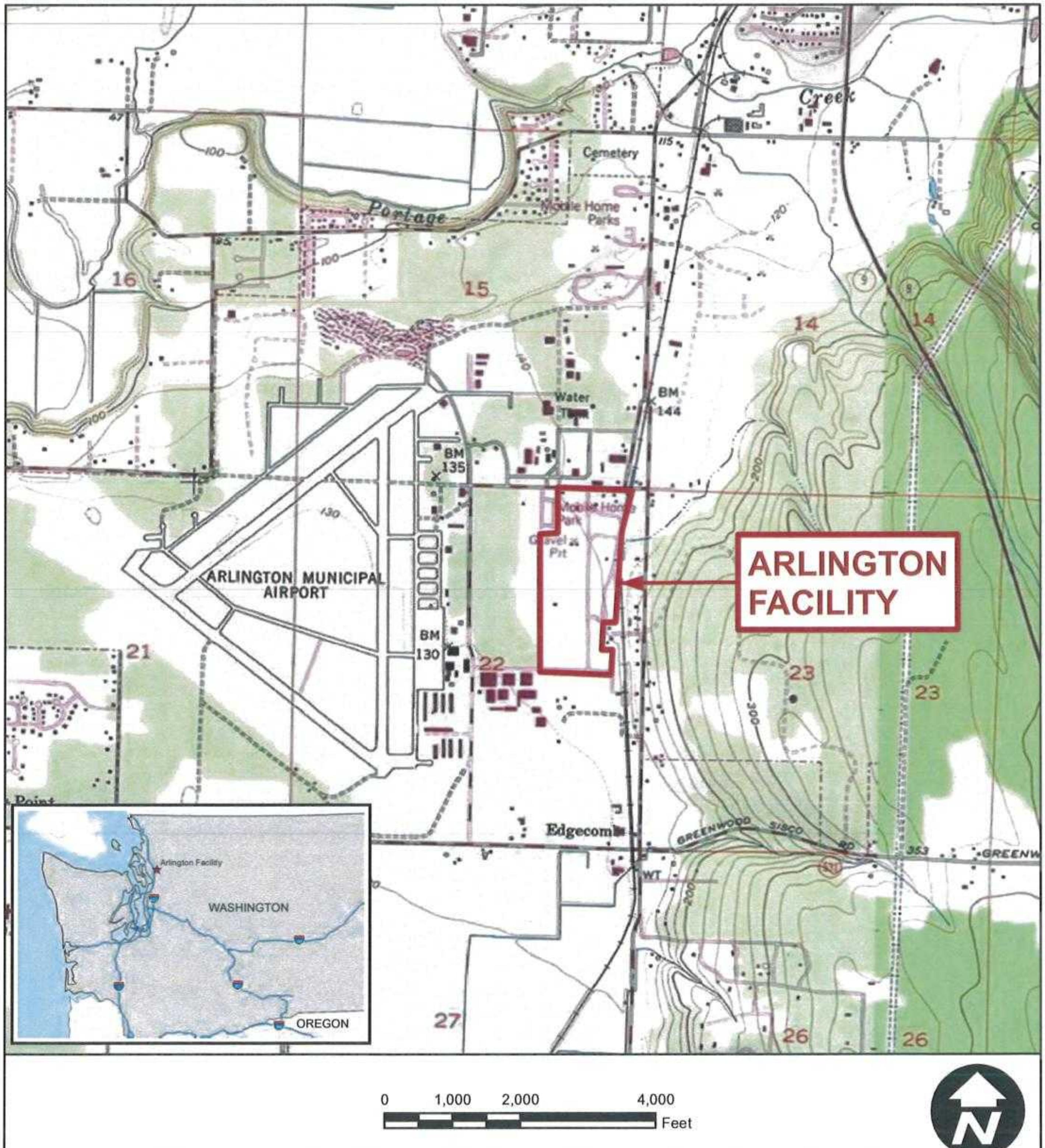
TABLE 8
Summary of All Bench Oxidation Effectiveness Testing Data
Former J.H. Baxter and Co. Wood Treating Facility
Arlington, Washington

Sample ID	Day 78				Day 102											
	Persulfate Dosage g/kg	pH s.u.	TOD g/kg	Residual Oxidant g/kg	Persulfate Dosage g/kg	pH s.u.	TOD g/kg	Residual Oxidant g/kg	As mg/L	Cr (total) mg/L	Cu mg/L	Pb mg/L	DRO mg/kg	DRO % Reduction	PCP mg/kg	PCP % Reduction
Round 2 (26Jun2014 through 14																
SB-D-30-33 - Control	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
SB-D-30-33 - Alk Pers	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
SB-A-24-27 - Control	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
SB-A-24-27 - Alk Pers	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Round 1 (18Nov2013 through 28																
SB-D-30-33 - Control	NT	6.30	NT	NT	NT	NT	NT	NT	<0.30	<0.050	<0.050	<0.30	13,000	-	130	-
SB-D-30-33 - Alk Pers	46.0	10.64	38.7	7.3	69.0	12.87	58.5	10.5	0.80	0.90	<0.050	<0.30	9,700	25%	4.6	96%
	92.0	12.90	52.7	39.3	115.0	13.13	59.5	55.5	0.90	1.17	<0.05	<0.30	13,000	0%	<3.8	>97%
SB-D-30-33 - H2O2/Pers	46.0	2.47	37.4	8.6	69.0	2.43	56.6	12.4	<0.30	1.04	2.21	<0.30	11,000	15%	51	61%
	92.0	2.38	47.9	44.1	115.0	2.33	52.3	62.7	<0.30	1.64	2.87	0.41	5,200	60%	27	79%
SB-D-30-33 - Fe Pers	46.0	2.42	37.4	8.6	69.0	2.35	56.8	12.2	<0.30	0.81	2.10	<0.30	8,200	37%	63	52%
	92.0	2.29	47.5	44.5	115.0	2.27	52.7	62.3	<0.30	1.26	2.61	<0.30	5,000	62%	30	77%
SB-D-30-33 - Na Perm	23.0	8.96	>23.0	0.0	69.0	8.89	39.1	29.9	0.33	2.23	<0.050	0.93	6,400	51%	31	76%
SB-A-24-27 - Control	NT	5.71	NT	NT	NT	NT	NT	NT	<0.30	<0.050	0.10	<0.30	3,400	-	31	-
SB-A-24-27 - Alk Pers	131.3	12.96	78.8	52.5	175	13.12	110	64.9	1.01	2.17	<0.050	<0.30	3,400	0%	<3.8	>88%
	262.5	12.97	205.3	57.2	350	13.05	278	72.3	1.50	3.00	<0.050	<0.30	4,700	-38%	<4.7	>85%
SB-A-24-27 - H2O2 Pers	131.3	2.62	64.2	67.1	175	2.10	92.5	82.5	0.32	2.53	4.00	0.51	2,700	21%	7.3	100%
	262.5	2.29	195.7	66.8	350	1.82	269	80.8	0.74	4.94	6.80	0.69	3,100	9%	7.4	100%
SB-A-24-27 - Fe Pers	131.3	2.43	65.1	66.2	175	2.05	92.0	83.0	0.37	2.29	3.81	0.47	2,600	24%	8.6	100%
	262.5	2.30	196.3	66.2	350	1.74	266	83.7	0.79	4.07	5.91	0.53	2,800	18%	11	100%
SB-A-24-27 - Na Perm	43.8	8.81	>43.8	0.0	87.6	8.77	29.6	58.0	0.65	4.14	<0.050	1.73	2,800	18%	<3.3	>89%

Notes
Alk Pers = Persulfate with alkaline activator
DRO = Diesel Range Organics
Fe Pers = Persulfate with iron activator
g/kg = grams per kilogram
H2O2 Pers = Persulfate with hydrogen peroxide activator
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
Na Perm = Sodium permanganate
NT = not tested
PCP = Pentachlorophenol
s.u. = standard pH units
- = not applicable

amec foster wheeler

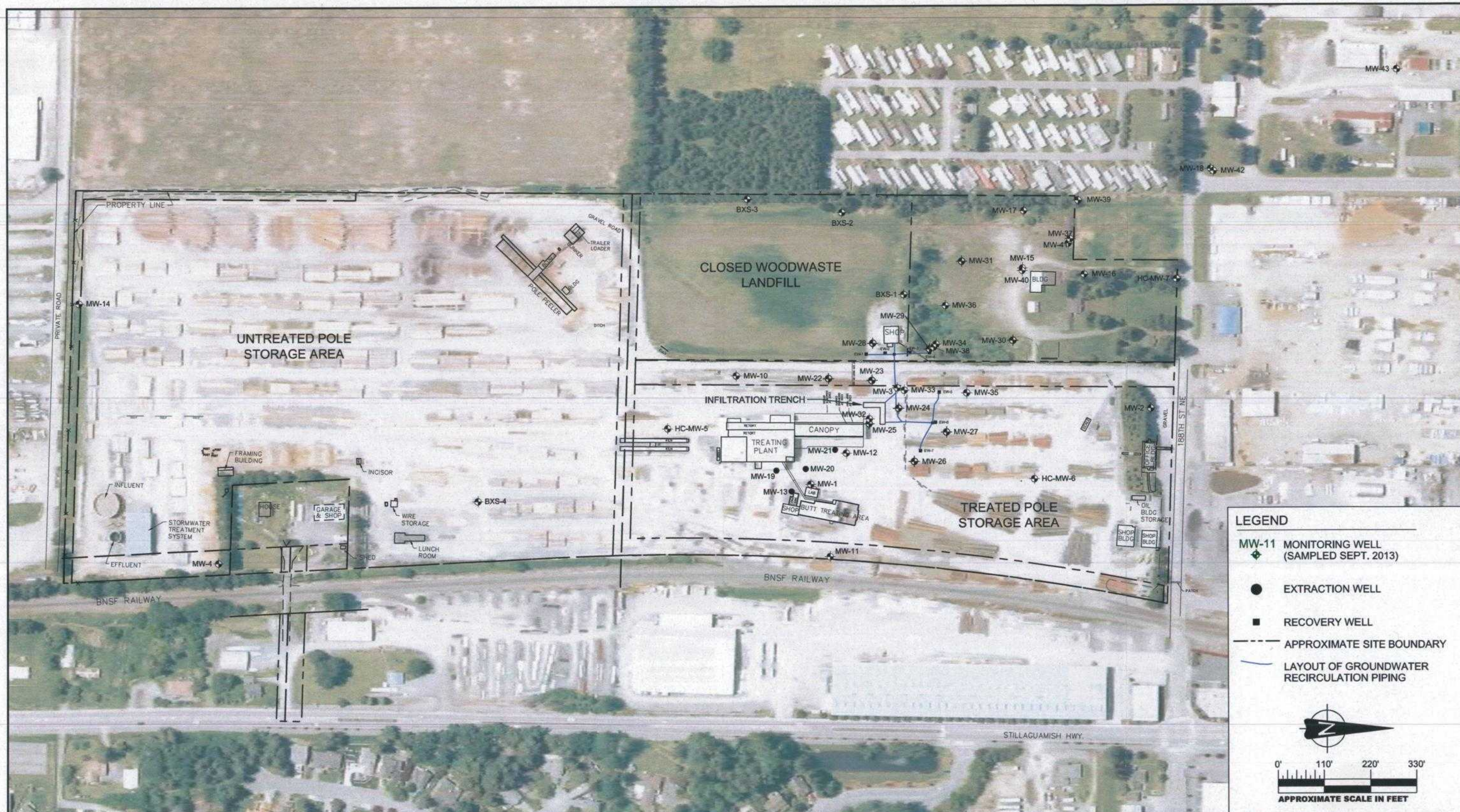
FIGURES



AMEC 7376 SW Durham Road Portland, OR, U.S.A. 97224	amec	J.H. Baxter	CLIENT: J.H. BAXTER

TITLE: SITE VICINITY MAP	DWN BY: PM	DATUM: NAD83	DATE: NOVEMBER 2014
PROJECT: FORMER J.H. BAXTER AND CO. WOOD TREATING FACILITY ARLINGTON, WA	CHK'D BY: JS	REV. NO.: 1	PROJECT NO.: 4-61M-125612
	PROJECTION: WA SP N. Ft.	SCALE: 1 inch = 2,000 feet	FIGURE NO.: 1

K:\12000\12500\12561\125612\DWG_Source_Bench_Report\Figure 1 - Site Vicinity Map.mxd - stephane.descombes - 11/20/2014 - 9:49:15 AM



AERIAL: MAY 2009, GOOGLE

CLIENT: J.H. BAXTER

JHBaxter

AMEC
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

amec

DWN BY:	APS/SD
CHK'D BY:	JS
DATUM:	-
PROJECTION:	-
SCALE:	AS SHOWN

PROJECT: FORMER J.H. BAXTER AND CO. WOOD TREATING FACILITY ARLINGTON, WA

TITLE: SITE PLAN & GROUNDWATER MONITORING NETWORK

DATE:	NOVEMBER 2014
PROJECT NO.:	4-61M-125612
REV. NO.:	A
FIGURE NO.:	2

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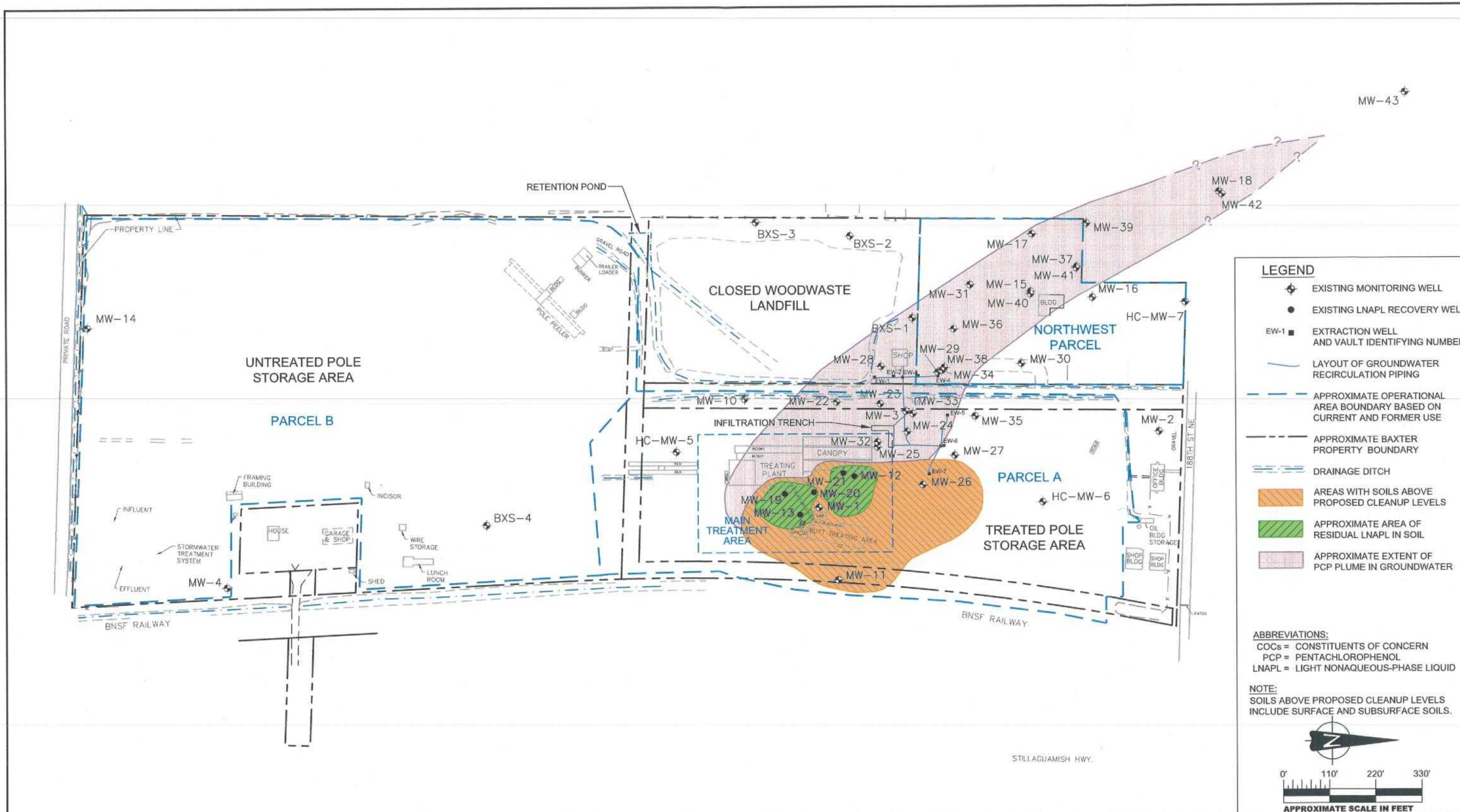

Figure originally published by AMEC in:
Corrective Measures Study - Revision 3
Former J.H. Baxter & Co. Wood Treating Facility, Arlington, Washington
April 2013

CLIENT: J.H. BAXTER	DWN BY: APS/PM	PROJECT: FORMER J.H. BAXTER AND CO. WOOD TREATING FACILITY ARLINGTON, WA
	CHK'D BY: JS	DATE: NOVEMBER 2014
	DATUM: -	PROJECT NO: 4-61M-125612
AMEC 7376 S.W. Durham Road Portland, OR. U.S.A. 97224	PROJECTION: -	TITLE: AREAS OF CONCERN
	SCALE: AS SHOWN	REV. NO.: A
		FIGURE No. 3

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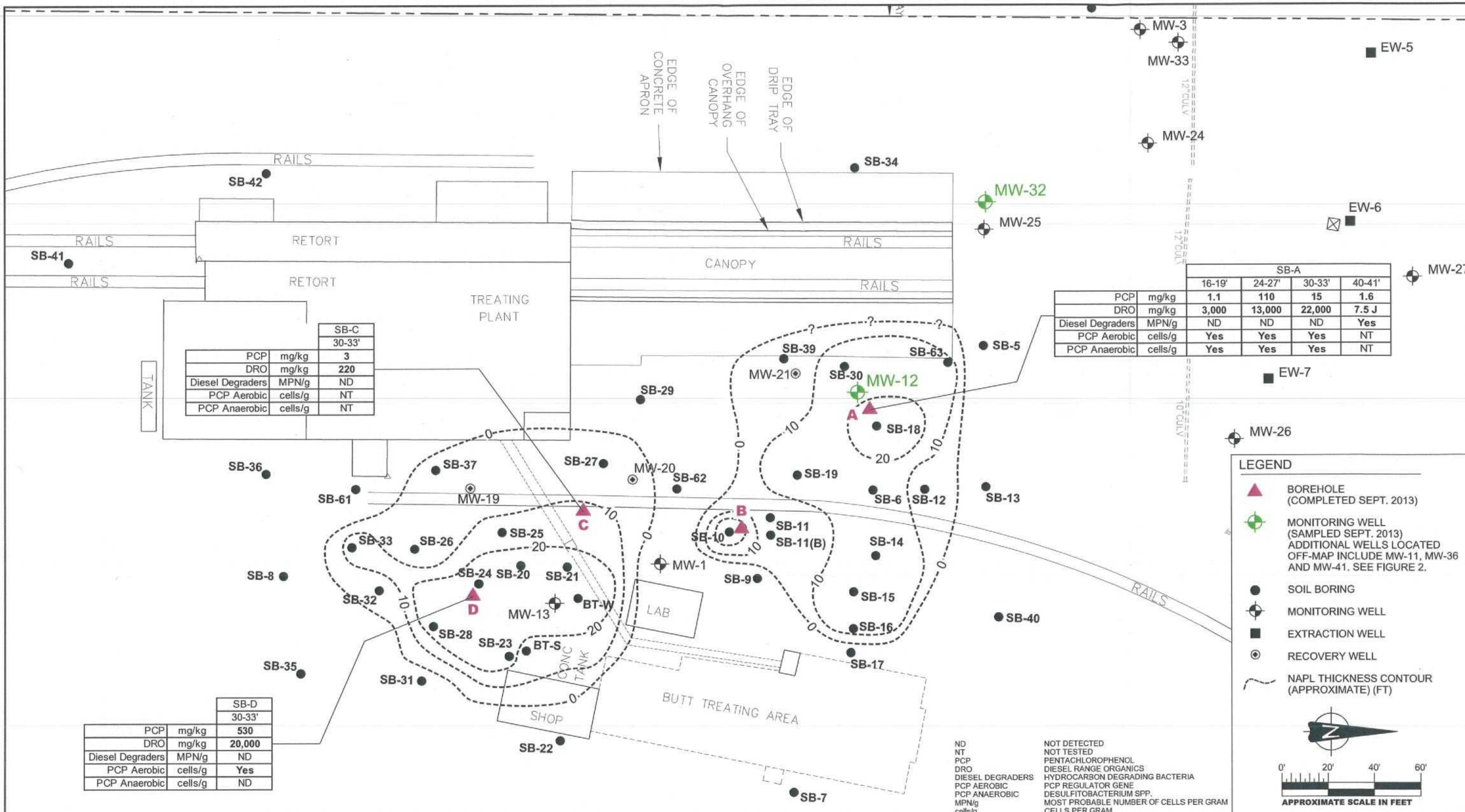


		SB-A			
		16-19'	24-27'	30-33'	40-41'
PCP	mg/kg	1.1	110	15	1.6
DRO	mg/kg	3,000	13,000	22,000	7.5 J
Diesel Degraders	MPN/g	ND	ND	ND	Yes
PCP Aerobic	cells/g	Yes	Yes	Yes	NT
PCP Anaerobic	cells/g	Yes	Yes	Yes	NT

		SB-C
		30-33'
PCP	mg/kg	3
DRO	mg/kg	220
Diesel Degraders	MPN/g	ND
PCP Aerobic	cells/g	NT
PCP Anaerobic	cells/g	NT

		SB-D
		30-33'
PCP	mg/kg	530
DRO	mg/kg	20,000
Diesel Degraders	MPN/g	ND
PCP Aerobic	cells/g	Yes
PCP Anaerobic	cells/g	ND

LEGEND

- BOREHOLE (COMPLETED SEPT. 2013)
- MONITORING WELL (SAMPLED SEPT. 2013) ADDITIONAL WELLS LOCATED OFF-MAP INCLUDE MW-11, MW-36 AND MW-41. SEE FIGURE 2.
- SOIL BORING
- MONITORING WELL
- EXTRACTION WELL
- RECOVERY WELL
- NAPL THICKNESS CONTOUR (APPROXIMATE) (FT)

ND	NOT DETECTED
NT	NOT TESTED
PCP	PENTACHLOROPHENOL
DRO	DIESEL RANGE ORGANICS
DIESEL DEGRADERS	HYDROCARBON DEGRADING BACTERIA
PCP AEROBIC	PCP REGULATOR GENE
PCP ANAEROBIC	DESULFITOBACTERIUM SPP.
MPN/g	MOST PROBABLE NUMBER OF CELLS PER GRAM
cells/g	CELLS PER GRAM

JHBaxter

CLIENT: J.H. BAXTER

AMEC
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

amec

DWN BY: JRS/SD
CHK'D BY: JS
DATUM: -
PROJECTION: -
SCALE: AS SHOWN

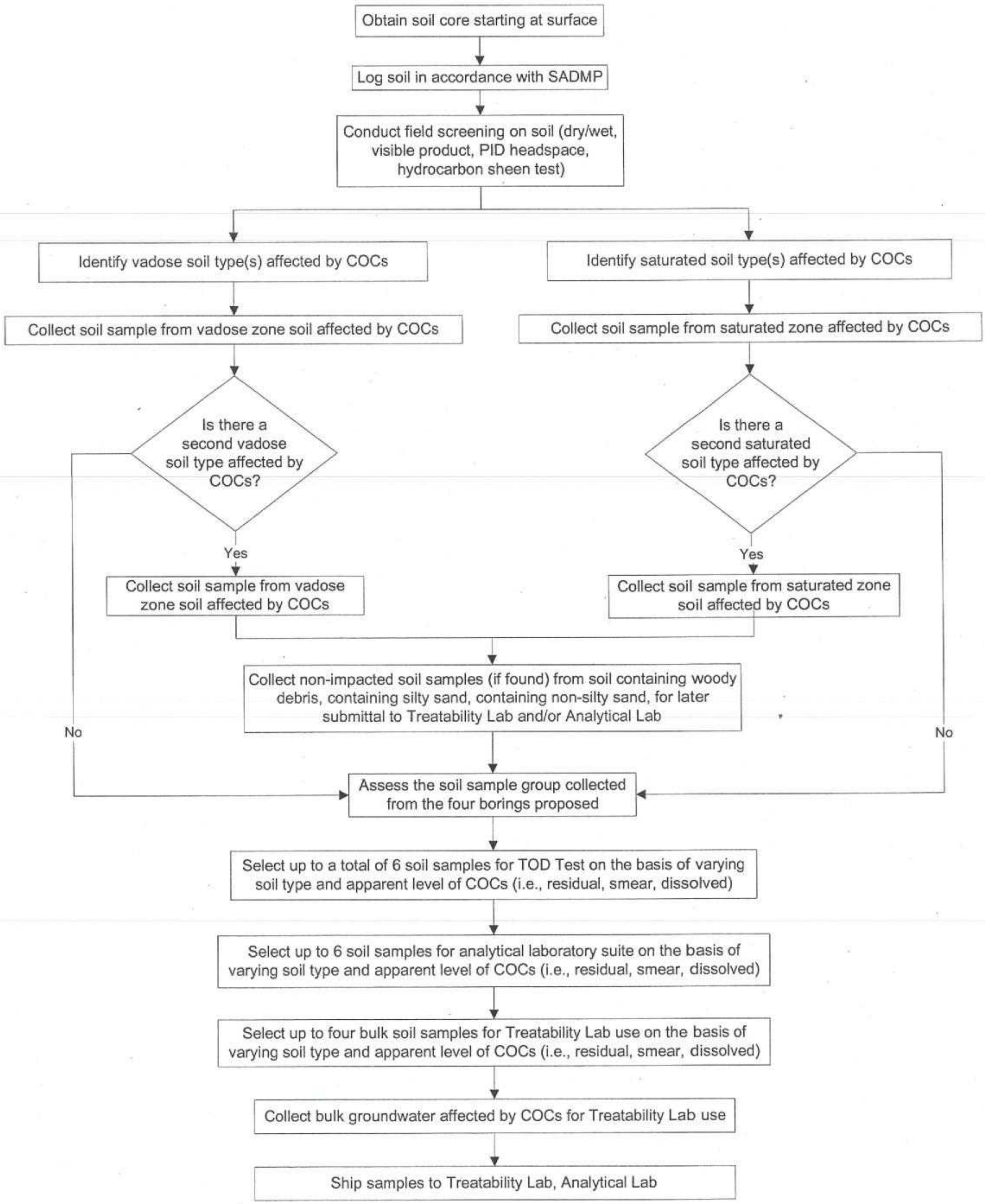
PROJECT: FORMER J.H. BAXTER AND CO. WOOD TREATING FACILITY ARLINGTON, WA

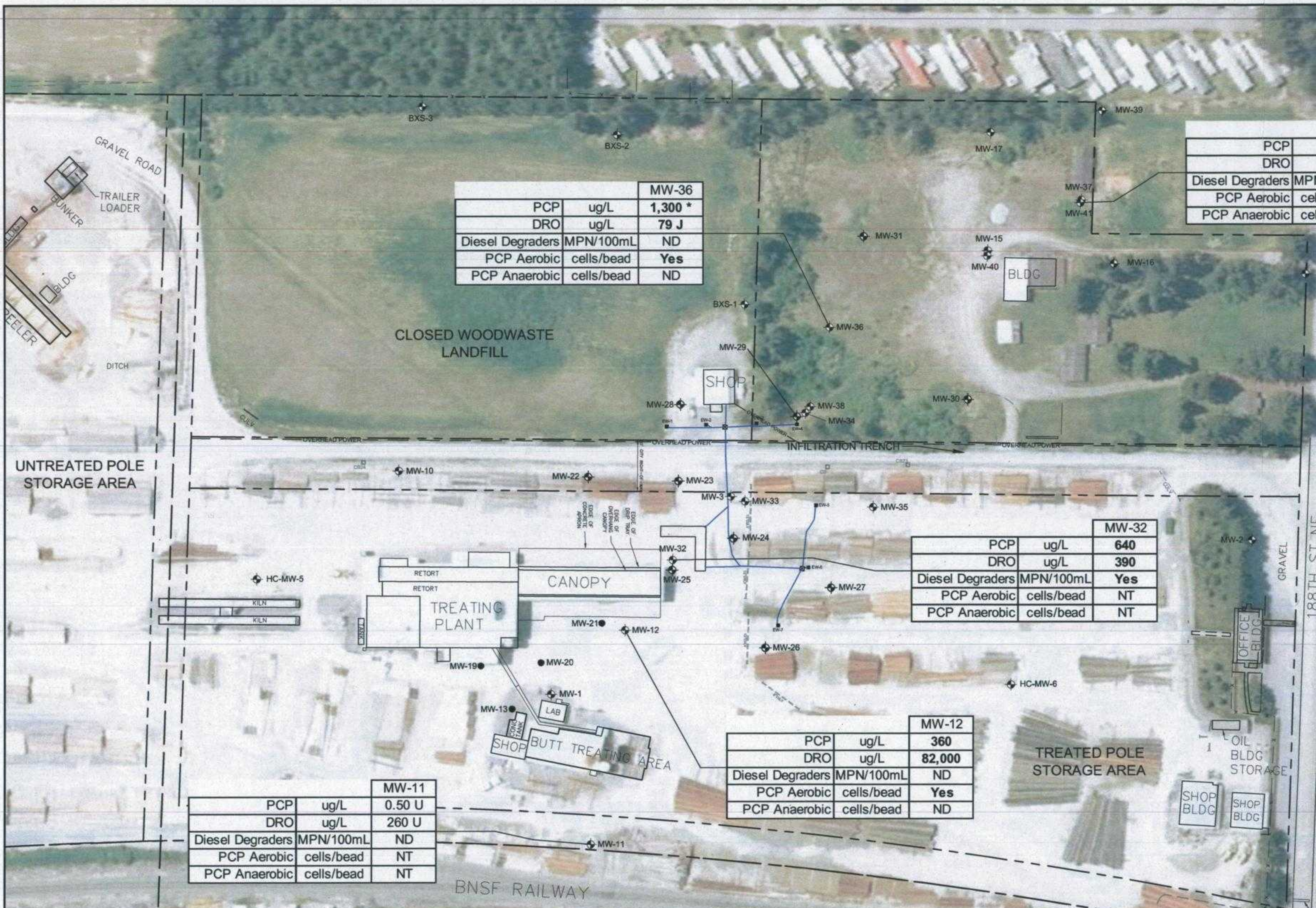
TITLE: BOREHOLE SOIL SAMPLING LOCATIONS AND RESULTS - SEPTEMBER 2013

DATE: NOVEMBER 2014
PROJECT NO.: 4-61M-125612
REV. NO.: A
FIGURE NO.: 4

K:\12000\12500\12561\125612\DWG_Source_Bench_Report\Figure 4 - Borehole Soil Sampling Locations and Results.dwg - - - Nov. 20, 2014 9:34am - stephane.descombes

FIGURE 5
SOIL SAMPLING GUIDE





		MW-36
PCP	ug/L	1,300 *
DRO	ug/L	79 J
Diesel Degraders	MPN/100mL	ND
PCP Aerobic	cells/bead	Yes
PCP Anaerobic	cells/bead	ND

		MW-41
PCP	ug/L	370
DRO	ug/L	200 J
Diesel Degraders	MPN/100mL	ND
PCP Aerobic	cells/bead	Yes
PCP Anaerobic	cells/bead	ND

		MW-32
PCP	ug/L	640
DRO	ug/L	390
Diesel Degraders	MPN/100mL	Yes
PCP Aerobic	cells/bead	NT
PCP Anaerobic	cells/bead	NT

		MW-12
PCP	ug/L	360
DRO	ug/L	82,000
Diesel Degraders	MPN/100mL	ND
PCP Aerobic	cells/bead	Yes
PCP Anaerobic	cells/bead	ND

		MW-11
PCP	ug/L	0.50 U
DRO	ug/L	260 U
Diesel Degraders	MPN/100mL	ND
PCP Aerobic	cells/bead	NT
PCP Anaerobic	cells/bead	NT

LEGEND

MW-11 MONITORING WELL (SAMPLED SEPT. 2013 FOR PCP, DRO AND HYDROCARBON DEGRADING BACTERIA) (SAMPLED DEC. 2013 FOR PCP DEGRADATION GENETIC MARKERS)

EXTRACTION WELL

RECOVERY WELL

APPROXIMATE SITE BOUNDARY

LAYOUT OF GROUNDWATER RECIRCULATION PIPING

0' 110' 220' 330'

APPROXIMATE SCALE IN FEET

ND	NOT DETECTED
NT	NOT TESTED
PCP	PENTACHLOROPHENOL
DRO	DIESEL RANGE ORGANICS
DIESEL DEGRADERS	HYDROCARBON DEGRADING BACTERIA
PCP AEROBIC	PCP REGULATOR GENE
PCP ANAEROBIC	DESULFITOBACTERIUM SPP.
MPN/g	MOST PROBABLE NUMBER OF CELLS PER GRAM
cells/g	CELLS PER GRAM
*	POTENTIALLY ANOMALOUS RESULT SUSPECTED TO BE 10X DILUTION, CORRECT RESULT MAY BE 130 µg/L

AERIAL: MAY 2009, GOOGLE

CLIENT: J.H. BAXTER

AMEC
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

DWN BY: APS/SD
CHK'D BY: JS
DATUM: -
PROJECTION: -
SCALE: AS SHOWN

PROJECT: FORMER J.H. BAXTER AND CO. WOOD TREATING FACILITY ARLINGTON, WA

TITLE: SUMMARY OF GROUNDWATER PCP, DRO & BIOLOGICAL MONITORING RESULTS SEPTEMBER/DECEMBER 2013

DATE: NOVEMBER 2014
PROJECT NO.: 4-61M-125612
REV. NO.: A
FIGURE NO.: 6

K:\12000\12500\12561\125612\DWG_Source_Bench_Report\Figure 2-6 - Groundwater Monitoring Network.dwg - 6 - Nov. 20, 2014 9:31am - stephone.descombes

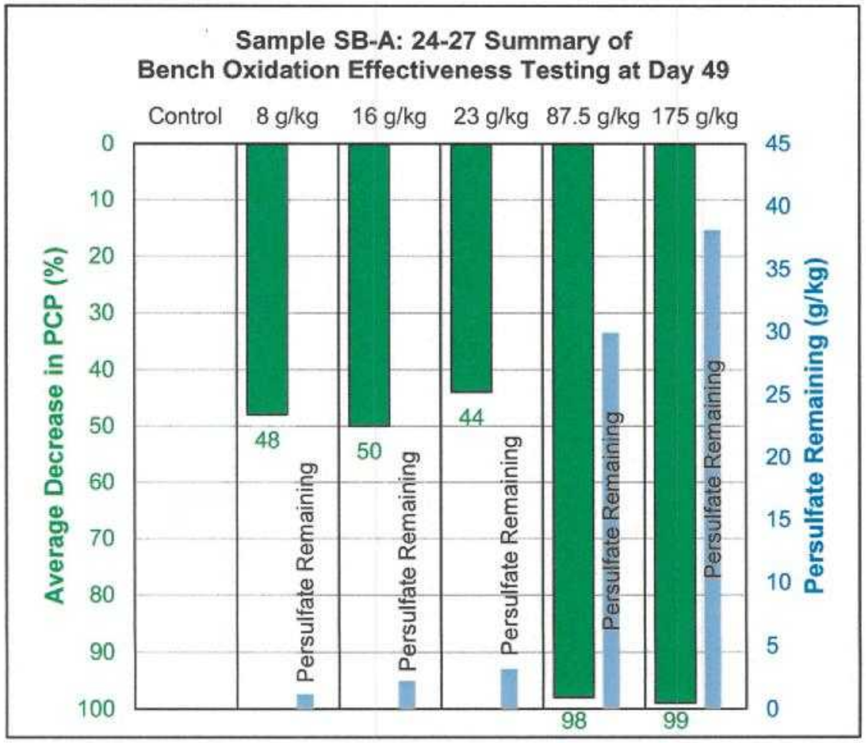
Figure 7
Pentachlorophenol (PCP) Oxidized vs Persulfate Used at Day 49
Former J.H. Baxter Co. Wood Treating Facility
Arlington, Washington

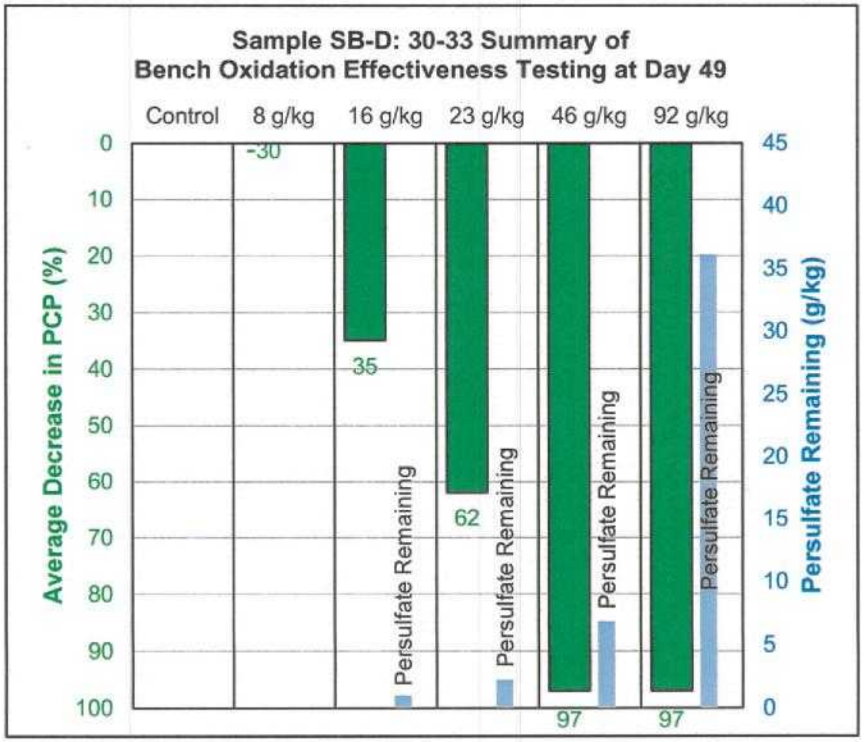
Sample SB-A: 24-27

Persulfate Dose	Average % Decrease in PCP	Persulfate Remaining (g/kg)
Control	0	0
8 g/kg	48	1.2
16 g/kg	50	2.2
23 g/kg	44	3.2
87.5 g/kg	98	29.9
175 g/kg	99	38.1

Sample SB-D: 30-33

Persulfate Dose	Average % Decrease in PCP	Persulfate Remaining (g/kg)
Control	0	0
8 g/kg	-30	0
16 g/kg	35	1
23 g/kg	62	2.2
46 g/kg	97	6.8
92 g/kg	97	36.1





ATTACHMENT A

Boring Logs

PROJECT: Former J.H. Baxter Arlington, Washington	**Log of Boring No. SB-A**
BORING LOCATION:	ELEVATION AND DATUM:
DRILLING CONTRACTOR: Cascade Drilling, Inc.	DATE STARTED: 9/20/13 — DATE FINISHED: 9/20/13
DRILLING METHOD: Sonic drilling	TOTAL DEPTH (ft.): 45.0 — MEASURING POINT:
DRILLING EQUIPMENT: Prosonic, Spider Track Mounted Limited Access Rig	DEPTH TO WATER (ft.) FIRST ~ 30 ft — COMPL.
SAMPLING METHOD: 5-foot-continuous-core system [5' x 4" OD]	LOGGED BY: Nathan Moxley
HAMMER WEIGHT: NA — DROP: NA	RESPONSIBLE PROFESSIONAL: Steve Barnett, LG — REG. NO. 1051

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:	REMARKS
0					AGGREGATE BASE (GP): Light grayish brown, moist, gravel with sand and silt (roadbase FILL) (no odor)	Bagged Samples Sheen Testing Results:
2				0.5		no sheen
5				0.4		no sheen
6					WOOD DEBRIS: Dark brown to black, moist, 95% WOOD DEBRIS, 5% fine sand (faint odor)	
7				5.2		no sheen
9					rock fragment	
9.5				2.1		no sheen
10–11	SB-A: 10 - 11					
12				0.0		no sheen
14				0.1		no sheen
15					POORLY-GRADED GRAVEL (GP): Gray, rounded cobble fragments	
15.5					POORLY-GRADED SAND with GRAVEL (SP): Gray, moist, 80% medium to coarse SAND with 15% rounded gravel, and 5% fine sand (odor)	
16	SB-A: 16 - 19			10.1		abundant sheen with product droplets
18				15.6		slight sheen
19					POORLY-GRADED SAND (SP): Light brown, moist, 85% fine to medium SAND with 10% coarse sand and 5% gravel (slight odor)	
20						

OAKBOREV (REV. 8/2011)

PROJECT: Former J.H. Baxter
Arlington, Washington

Log of Boring No. SB-A (cont'd)

DEPTH (feet)	Sample No.	Sample	Blows/ Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	REMARKS
20-21				5.6	WOOD DEBRIS: Dark brown to black, moist, 95% WOOD DEBRIS, 5% fine sand (faint odor)	abundant sheen with product droplets
21-22					Gray, silty, fine SAND lense	
22				1.8	POORLY-GRADED SAND with GRAVEL (SP): Gray, moist, 75% medium to coarse SAND with 15% rounded gravel, 5% fine sand, and 5% wood debris (odor and staining)	no sheen
23-24					POORLY-GRADED SAND (SP): Grayish brown, moist, 90% fine to medium SAND with 5% coarse sand and 5% gravel (odor and staining)	
24-25	SB-A: 24 - 27			15.8		abundant sheen with product droplets
26				16.0		abundant sheen with product droplets
27-28						
29				19.0	POORLY-GRADED SAND with SILT (SP-SM): Light brown, moist, 85% fine SAND with 10% silt and 5% gravel (odor and staining)	abundant sheen with product droplets
30	SB-A: 30 - 33				becomes wet	
31				22.8		free product visible
33				16.1	residual free product visible in core bag at 33 ft	free product visible
35						slight sheen
36				0.1		no sheen
39				0.5		
40	SB-A: 40 - 41					no sheen
41				0.3		
42						no sheen
43-44						

OAKBOREV (REV. 8/2011)

PROJECT: Former J.H. Baxter
Arlington, Washington

Log of Boring No. SB-A (cont'd)

DEPTH (feet)	Sample No.	Sample	Blows/ Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	REMARKS
45				0.0		no sheen
46					Boring terminated at 45 feet and backfilled with bentonite chips	
47						
48						
49						
50						
51						
52						
53						
54						
55						
56						
57						
58						
59						
60						
61						
62						
63						
64						
65						
66						
67						
68						

OAKBOREV (REV. 8/2011)

PROJECT: Former J.H. Baxter Arlington, Washington	**Log of Boring No. SB-B**		
BORING LOCATION:	ELEVATION AND DATUM:		
DRILLING CONTRACTOR: Cascade Drilling, Inc.	DATE STARTED: 9/20/13	DATE FINISHED: 9/20/13	
DRILLING METHOD: Sonic drilling	TOTAL DEPTH (ft.): 40.0	MEASURING POINT:	
DRILLING EQUIPMENT: Prosonic, Spider Track Mounted Limited Access Rig	DEPTH TO WATER (ft.)	FIRST ~ 30 ft	COMPL.
SAMPLING METHOD: 5-foot-continuous-core system [5' x 4" OD]	LOGGED BY: Nathan Moxley		
HAMMER WEIGHT: NA DROP: NA	RESPONSIBLE PROFESSIONAL: Steve Barnett, LG		REG. NO. 1051

DEPTH (feet)	SAMPLES: Sample No.	Sample	Blows/ Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:	REMARKS
0–1					AGGREGATE BASE (GP): Light grayish brown, moist, gravel with sand and silt (roadbase FILL) (no odor)	Bagged Samples Sheen Testing Results:
2				2.1		no sheen
3.5					WOOD DEBRIS: Dark brown to black, moist, 95% WOOD DEBRIS, 5% fine sand (faint odor)	
4.5				1.6	POORLY-GRADED SAND (SP): Light grayish brown, moist, 90% fine to medium SAND with 5% silt and 5% gravel (no odor)	no sheen
6				3.3	POORLY-GRADED SAND (SP): Light grayish brown with reddish gray and gray staining, moist, 60% medium to coarse SAND with 30% fine sand and 10% gravel (slight odor)	slight sheen
9				1.4		no sheen
10–11				6.8	POORLY-GRADED SAND with GRAVEL (SP): Light grayish brown with dark gray staining, moist, 65% medium to coarse SAND with 25% gravel and 10% fine sand (no odor)	no sheen
14				2.0		no sheen
16				1.1	contains rounded cobbles	no sheen
18–20	SB-B: 18 - 20	■		0.6		no sheen

OAKBOREV (REV. 8/2011)

PROJECT: Former J.H. Baxter
Arlington, Washington

Log of Boring No. SB-B (cont'd)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	REMARKS
21				2.4	POORLY-GRADED SAND (SP): Light brown with gray staining, moist, 80% fine to medium SAND, with 10% coarse sand and 10% gravel (slight odor)	no sheen
22						
23						
24				1.2		no sheen
25					no staining visible	
26				3.0		slight sheen
27						
28					general grain size decreases to 95% fine to medium SAND with 5% gravel	
29				2.6		no sheen
30						
31				15.9	free product visible inside core bag	abundant sheen with product droplets
32						
33				15.4	POORLY-GRADED SAND with SILT (SP-SM): Light brown, wet, 85% fine SAND with 15% silt (odor)	free product visible
34						
35						
36				5.5		slight sheen
37						
38						
39				2.8		no sheen
40					Boring terminated at 40 feet and backfilled with bentonite chips.	
41						
42						
43						
44						

PROJECT: Former J.H. Baxter Arlington, Washington		**Log of Boring No. SB-C**		
BORING LOCATION:		ELEVATION AND DATUM:		
DRILLING CONTRACTOR: Cascade Drilling, Inc.		DATE STARTED: 9/20/13	DATE FINISHED: 9/20/13	
DRILLING METHOD: Sonic drilling		TOTAL DEPTH (ft.): 40.0	MEASURING POINT:	
DRILLING EQUIPMENT: Prosonic, Spider Track Mounted Limited Access Rig		DEPTH TO WATER (ft.)	FIRST ~ 30 ft	COMPL.
SAMPLING METHOD: 5-foot-continuous-core system [5' x 4" OD]		LOGGED BY: Nathan Moxley		
HAMMER WEIGHT: NA	DROP: NA	RESPONSIBLE PROFESSIONAL: Steve Barnett, LG		REG. NO. 1051

DEPTH (feet)	SAMPLES: Sample No.	Sample	Blows/ Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:	REMARKS
0					AGGREGATE BASE (GP): Light grayish brown, moist, gravel with sand and silt (roadbase FILL) (no odor)	Bagged Samples Sheen Testing Results:
2				1.3		no sheen
3.5					POORLY-GRADED SAND with SILT (SP-SM): Brown, moist, 75% fine to medium SAND with 15% silt and 10% gravel (slight odor)	
4.5				5.1		no sheen
5					POORLY-GRADED SAND (SP): Light grayish brown, moist, 85% fine to medium SAND with 10% gravel and 5% coarse sand (no odor)	
6				5.8		slight sheen
8.5				3.5		no sheen
10					coarse sand content increases	
12				1.0		no sheen
14				1.7		no sheen
16				1.9	POORLY-GRADED SAND (SP): Light brown, moist, 80% medium to coarse SAND, with 10% fine sand and 10% gravel (no odor)	no sheen
19				1.6		no sheen
20						

OAKBOREV (REV. 8/2011)

PROJECT: Former J.H. Baxter
Arlington, Washington

Log of Boring No. SB-C (cont'd)

DEPTH (feet)	Sample No.	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	REMARKS
21	SB-C: 20 - 21	2.3		no sheen
22				
23			grain size decreases to a fine to medium SAND	
24		1.4		no sheen
25			grain size increases to a medium to coarse SAND	
26		3.5	gravel lense	no sheen
27				
28		6.2	gravelly, medium to coarse SAND lense	sheen with trace product droplets
29			POORLY-GRADED SAND with SILT (SP-SM): Light brown, moist, 90% fine SAND, with 10% silt (no odor)	
30		4.0	becomes wet	no sheen
31	SB-C: 30 - 33		lense containing 10% coarse sand and 10% gravel	
32		5.9		no sheen
33				
34				
35		3.7		no sheen
36		2.3		no sheen
37				
38				
39		1.4		no sheen
40				
41			Boring terminated at 40 feet and backfilled with bentonite chips.	
42				
43				
44				

OAKBOREV (REV. 8/2011)

PROJECT: Former J.H. Baxter Arlington, Washington	**Log of Boring No. SB-D**		
BORING LOCATION:	ELEVATION AND DATUM:		
DRILLING CONTRACTOR: Cascade Drilling, Inc.	DATE STARTED: 9/20/13	DATE FINISHED: 9/20/13	
DRILLING METHOD: Sonic drilling	TOTAL DEPTH (ft.): 40.0	MEASURING POINT:	
DRILLING EQUIPMENT: Prosonic, Spider Track Mounted Limited Access Rig	DEPTH TO WATER (ft.)	FIRST ~ 30 ft	COMPL.
SAMPLING METHOD: 5-foot-continuous-core system [5' x 4" OD]	LOGGED BY: Nathan Moxley		
HAMMER WEIGHT: NA DROP: NA	RESPONSIBLE PROFESSIONAL: Steve Barnett, LG		REG. NO. 1051

DEPTH (feet)	Sample No.	Sample	Blows/ Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:	REMARKS
0–2					AGGREGATE BASE (GP): Light grayish brown, moist, gravel with sand and silt (roadbase FILL) (no odor)	Bagged Samples Sheen Testing Results:
2				2.4	POORLY-GRADED SAND (SP): Light grayish brown, moist, 90% fine to medium SAND with 5% coarse sand and 5% gravel (no odor)	no sheen
3.5					dark brown color	
4				1.5		no sheen
6				1.5		no sheen
8				2.1		no sheen
9					POORLY-GRADED SAND with GRAVEL (SP): Light grayish brown, moist, 60% medium to coarse SAND with 30% gravel and 10% fine sand (no odor)	
10.5					POORLY-GRADED SAND (SP): Light grayish brown, moist, 90% fine to medium SAND with 10% gravel (no odor)	
11				2.8		no sheen
14				1.8		no sheen
16				3.1	POORLY-GRADED SAND with GRAVEL (SP): Light grayish brown, moist, 60% medium to coarse SAND with 30% gravel and 10% fine sand (no odor)	no sheen
18				3		no sheen
20						

OAKBOREV (REV. 8/2011)

PROJECT: Former J.H. Baxter
Arlington, Washington

Log of Boring No. SB-D (cont'd)

DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM READING (ppm)	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	REMARKS
21				2.8	POORLY-GRADED SAND (SP): Light grayish brown, moist, 90% fine to medium SAND with 10% gravel (no odor)	no sheen
22						
23						
24				3.3		no sheen
25						
26				3.4		no sheen
27					POORLY-GRADED SAND with GRAVEL (SP): Light grayish brown, moist, 60% medium to coarse SAND with 30% gravel and 10% fine sand (odor and staining)	
28				21.4		slight sheen
29						
30	SB-D: 30 - 33			17.7	POORLY-GRADED SAND with SILT (SP-SM): Light brown, moist to wet, 90% fine to medium SAND with 10% silt (strong odor) visible product in soil core from 30 - 34 ft	sheen and product droplets
31						
32				17.1		heavy sheen and free product
33						
34					odor decreases below 34 ft	
35				4.6		slight sheen
36				2.7		no sheen
37						
38				3.0		
39						
40				1.7	Boring terminated at 40 feet and backfilled with bentonite chips.	no sheen
41						
42						
43						
44						

ATTACHMENT B

Soil and Groundwater Laboratory Analytical Reports

ATTACHMENT C

Ursus Bench Treatability Study Report

200 E Lincoln Street
Mount Horeb, WI 53572
(608) 437-7413

October 28, 2014

Dr. Jack Spadaro
AMEC Environment & Infrastructure
7376 SW Durham Road
Portland, Oregon 97224

Subject: Bench Level Testing for the Remediation of Pentachlorophenol at the JH Baxter site in Arlington, WA.

Dr. Spadaro,

Ursus Remediation Testing & Technologies, LLC (Ursus) is pleased to provide AMEC Environment & Infrastructure (AMEC) this report for bench level testing of Pentachlorophenol (PCP) at the JH Baxter site in Arlington, WA.

OBJECTIVE

Testing was conducted to measure the effectiveness of chemical oxidants to reduce the levels of PCP in saturated soil from the site. Since a site specific PCP cleanup goal was not defined, the treatment goal was to reduce the mass of PCP in soil and groundwater slurries. PCP at the site is cut with diesel.

The two chemical oxidants tested in the study were persulfate and permanganate. Treatment of PCP contaminated soil and groundwater with persulfate is well established. Permanganate was evaluated since it has minimal potential to oxidize diesel range hydrocarbons and should be effective in mineralizing PCP. Therefore, the permanganate requirement may be lower than the persulfate requirement since the permanganate may target the PCP and to a lesser degree diesel.

The objectives of the study included:

1. Determine the Total Oxidant Demand (TOD) of soil using sodium persulfate and permanganate. The objective of the TOD is to determine the amount of persulfate and permanganate required to oxidize natural and anthropogenic sources of organic compounds in site soil.

2. Measure the effectiveness of varying dosages of persulfate and permanganate to lower concentrations of PCP in soil and groundwater slurries. Analyze secondary parameters to gauge the oxidant impact on groundwater.

3. PCP at the site is cut with diesel and it was suspected that free product diesel will increase the oxidant demand well above the stoichiometric mass of oxidant needed to mineralize only the PCP. Therefore, chemical dosing in the first round of evaluation testing took into consideration the potential oxidant demand of the diesel.

BACKGROUND

Seven soil samples and one groundwater sample were received by Ursus. Soil samples were collected in 16 oz. soil jars and received on ice. Groundwater was received on ice in 1 liter amber bottles. Samples were received unpreserved and were not chemically preserved at the laboratory for TOD and Effectiveness testing, which is standard operating procedure for this type of testing. Samples received, descriptions, and comments are shown in Table 1.

Table 1.
Samples Received for TOD and Effectiveness Testing

Sample Name	Sample Date	Date Received	Matrix	Wt. /vol	Sample Comments
MW-12	9/21/13	9/25/13 and 9/26/13	GW	12 L	No headspace
SB-A: 10-11	9/21/13	9/25/13	Soil	1-16 oz jars	Soil and plant debris. No apparent odor.
SB-C: 20-21	9/21/13	9/25/13	Soil	1-16 oz jars	Silty Loam. No apparent odor.
SB-A: 30-33	9/21/13	9/25/13 and 9/26/13	Soil	5-16 oz jars	Sandy Loam. Odor.
SB-D: 30-33	9/21/13	9/25/13	Soil	5-16 oz jars	Sandy Loam. Odor and free product.
SB-A: 16-19	9/21/13	9/26/13	Soil	5-16 oz jars	Small gravel and sand. Odor.
SB-A: 24-27	9/21/13	9/26/13	Soil	5-16 oz jars	Sandy soil. Odor.

Sodium persulfate requires activation to be the most effective in degrading contaminants in soil and groundwater. Common activators for persulfate include alkaline (sodium hydroxide), hydrogen peroxide, and transitional metals (iron). For this study, persulfate was activated with sodium hydroxide to a pH greater than 10.5, or hydrogen peroxide, or iron. Permanganate does not require activation for effective treatment.

MATERIAL & METHODOLOGY

Materials

- Sodium Persulfate – $Na_2S_2O_8$. Provided by PeroxyChem under the trade name Klozur™.
- Sodium Permanganate – 40% $NaMnO_4$. Provided by Carus Chemical under the trade name Remox® L ISCO.
- Hydrogen Peroxide – 30% H_2O_2. Fisher Scientific reagent grade.
- Ferrous Sulfate Heptahydrate - $FeSO_4 \cdot 7H_2O$. Premier Chemicals LLC.
- Sodium Hydroxide – NaOH. JT Baker reagent grade.

Analytical Methods

Both standard and non-standard methods were used during the study. Table 2 lists the methodologies.

Table 2.
Analytical Methodology

Test Parameter	Methodology
TOD/Effectiveness Testing	Haselow et. al (2003). FMC Protocol. Ursus Proprietary methodology
Diesel Range Organics (DRO)	EPA 8015C
Pentachlorophenol (PCP)	EPA 8270D
Total Arsenic, Chromium, Copper, Lead	EPA 6010
pH	SW-845 9045

Acidity and TOD Testing

Acidity was measured in each soil sample to determine the amount of sodium hydroxide needed to maintain the pH above 10.5 for alkaline activation. Acidity testing was conducted over roughly a 3-day period with periodic pH measurements and adjustment to maintain a greater than 10.5 pH. Alkalinity testing was conducted over roughly a 24 hour period with periodic pH measurements and adjustment to maintain the pH target range of 3 to 5 with sulfuric acid.

Soil slurries were prepared for TOD testing by mixing each soil with MW-12 groundwater. A soil to groundwater ratio of 1:4 was used in preparing the slurries. Oxidant/activator and groundwater where mixed and the mixture was added to the soil. Slurries were dosed with sodium persulfate at 2.5 g/kg, 5.0 g/kg, and 10.0 g/kg and the amount of alkalinity needed to maintain a greater than 10.5 pH. Only alkaline activation was tested for persulfate TOD. Permanganate TOD testing was dosed with 2.5 g/kg, 5.0 g/kg and 10.0 g/kg permanganate. Activation is not required for permanganate.

The samples were exposed to ambient laboratory conditions at the bench in tightly capped reaction jars with periodic mixing (shaken two to three times/day). TOD analysis was performed 48 and 96 hours post treatment.

Effectiveness Testing Round 1 (102 Day Treatment)

Two soil/groundwater slurry samples (one from SB-A: 24-27, and one from SB-D: 30-33) were prepared for effectiveness testing. Each soil was slurried with groundwater sample from MW- 12.

Samples were treated with alkaline activated sodium persulfate, hydrogen peroxide activated sodium persulfate, iron activated sodium persulfate, and sodium permanganate. Effectiveness testing dosages were based on data collected in TOD testing and oxidant stoichiometric demand of the DRO, heavy hydrocarbons, and PCP.

Analytical data showed significant concentrations of DRO, heavy hydrocarbons, and PCP in the soil. To ensure sufficient persulfate dosage to treat the contaminants, a stoichiometric calculation was performed to estimate the overall oxidant demand. The stoichiometric demand assumed persulfate will oxidize DRO, heavier hydrocarbons, and PCP at the same rate.

Due to the high oxidant demand of the soils and the difficulty of adding all of the chemistry in one application, persulfate and permanganate were added in multiple applications.

A control sample for each soil was prepared at the same soil to liquid ratio at the treated samples.

A sacrificial sample was prepared with the same chemistries and dosages to measure the secondary parameters, including residual persulfate and permanganate, arsenic, chromium, copper, lead, and pH. The secondary parameters were measured in the liquid phase of the sacrificial control and treated samples periodically during the study. Sacrificial samples were prepared since significant volume of the liquid phase may be required for secondary testing.

The control and treated samples (non-sacrificial sample) will be measured for DRO and PCP at two testing times. Sodium sulfite was added to treated and control samples submitted for DRO and PCP analysis to chemically reduce the oxidant and stop the reaction. Sodium sulfite was added immediately prior to sample submission. Each soil/groundwater slurry sample was amended with drying agent in the analytical laboratory, and the resulting solid was solvent-extracted to prepare a sample for injection into the gas chromatograph. Treated and control samples were corrected for total solids and results were reported as dry weight.

Persulfate Treatment

1. The target total persulfate dosage applied was 25% and 50% of the stoichiometric demand. One sample received a total of 25% of the total stoichiometric demand and another received 50% of the total stoichiometric demand. Residual persulfate was periodically monitored, depending on the residual persulfate concentration, add additional persulfate – if all or most of the persulfate is spent- or let the reaction proceed if significant persulfate remains and measure the persulfate concentration again over time.
2. The additional persulfate dosage, if required, was dependent on the residual persulfate and stoichiometric amount added.
3. DRO, PCP, and secondary parameters analysis time frames were dependent on data obtained in residual testing and the stoichiometric amount of oxidant added.

Permanganate Treatment

1. Because permanganate is generally not effective in oxidizing hydrocarbons, it is difficult to estimate the stoichiometric demand. Therefore, the persulfate demand was used as an estimate.
2. To allow for flexibility in adding permanganate, three samples were prepared and dosed at 25% of the persulfate demand.
3. The residual permanganate was monitored (visually) and analytically. Additional permanganate was added, if necessary. The additional permanganate dosage, if required, was dependent on the residual permanganate and initial dosage.
4. DRO, PCP, and secondary parameters analysis time frames were dependent on data obtained in residual testing and the stoichiometric amount of oxidant added.

For persulfate and permanganate effectiveness testing, 50 g of soil was tested and 12.5 mls of MW-12 groundwater was added at each dosage interval. For example, 12.5 mls of liquid was added in the first application. The second application also received 12.5 mls of liquid for a total volume of 25 mls. Each subsequent addition received another 12.5 mls of MW-12. The 50g of soil to 12.5 mls of liquid simulates a soil groundwater condition that is slightly greater than the saturation point. Laboratory testing found a soil saturation point of 23% v/v. The objective was to add a liquid volume that simulates a volume that could be added in an ISCO application.

The required amount of treatment chemical for each dosage was mixed with MW-12, and added to the corresponding soil. For alkaline activated sodium persulfate effectiveness testing, sodium hydroxide was applied to achieve a pH of greater than 10.5. The amount of sodium hydroxide required included the amount to increase the soil pH and to compensate for the formation of sulfuric acid from sodium persulfate. When sodium persulfate reacts, sulfuric acid is produced as a product of the reaction. Hydrogen peroxide was added at a 1:1 persulfate to peroxide molar ratio for peroxide activate sodium persulfate. For iron activated sodium persulfate, iron, in the form of ferrous sulfate heptahydrate, was added at 300 mg Fe/kg soil.

Effectiveness Testing Round 2 (49 Day Treatment)

Testing was conducted similarly to the first round of testing. Three alkaline activated dosages of 8, 16, and 23 g persulfate/kg soil where tested in samples SB-D-30-33 and SB-A-24-27. Fifty grams of soil was mixed with 12 mls of MW-12 groundwater at each dosage. A control sample at the same soil to liquid ratio was also prepared. A sacrificial sample was prepared at each dosage to measure the secondary parameters, including residual persulfate, and pH. Samples were allowed to react for 49 days and then samples were tested for residual persulfate, pH, PCP, and DRO. A duplicate was prepared for each control and dosage. Only PCP was measured in the duplicate.

RESULTS

Acidity and TOD Testing

The amount of sodium hydroxide needed to adjust the sample for alkaline activation includes the mass needed to maintain the pH above 10.5 and the mass needed to compensate for the decomposition of sodium persulfate and formation of sulfuric acid. The average baseline acidity for all soil samples was 2.75g NaOH/kg. The required amount of sodium hydroxide for each dosage is shown in Table 3.

Table 3.
Grams of NaOH Added For TOD Alkaline Activation.

Persulfate Dosage (g/kg)	Acidity (g NaOH/kg soil)
2.5	6.3
5.0	7.2
10.0	9.0

TOD Testing

Alkaline Persulfate TOD
Soil was dosed 2.5, 5.0, and 10.0 g/kg of sodium persulfate. The TOD was measured at 48 and 96 hours post treatment. The TOD was set up on September 30, 2013. The 48 hour persulfate TOD (TOD_{48Hr}) was measured on October 3, 2013 and the 96 hour (TOD_{96Hr}) on October 4, 2013.

At the 48 and 96 hour mark, the soil slurry was allowed to settle and an aliquot of the liquid fraction was decanted and analyzed for residual persulfate. The data for the TOD is shown in Table 4. Results are discussed below.

1. Higher dosage levels produced higher TOD results in both the 48 and 96 hour tests.

2. Higher results were observed in the TOD_{96} when compared to the TOD_{48} - suggesting that the majority of the oxidant demand was not met in the first 48 hours.

3. Where residual persulfate exists, the pH was significantly higher than the target pH of 10.5. This is not unexpected since more sodium hydroxide was added to compensate for the formation of sulfuric acid when the persulfate breaks down. Since all of the persulfate has not broken down, excess sodium hydroxide is present and therefore a higher pH results.

4. Where all of the sodium persulfate is utilized, the pH is near or less than 10.5.

5. TOD results show that SB-A: 10-11 and SB-C: 20-21 had the greatest TOD (> 10.0) while the other samples showed less TOD – ranging from 0.9 to 4.5 g/kg at 96 hours.

Table 4.
TOD_{48} and TOD_{96} Results for Alkaline Activation

		48 hour TOD		96 hour TOD	
Sample ID	**Sodium Persulfate Dosage g/kg**	**pH**	**g/kg**	**pH**	**g/kg**
SB-A: 10-11	2.5	9.54	> 2.5	8.41	> 2.5
	5.0	8.86	> 5.0	7.71	> 5.0
	10.0	7.90	> 10.0	6.99	> 10.0
SB-C: 20-21	2.5	11.48	> 2.5	10.78	> 2.5
	5.0	11.51	> 5.0	10.55	> 5.0
	10.0	12.02	6.2	11.44	> 10.0
SB-A: 30-33	2.5	12.21	0.2	12.24	1.1
	5.0	12.36	0.8	12.40	0.9
	10.0	12.57	0.9	12.60	3.3
SB-D: 30-33	2.5	12.17	1.0	12.03	1.0
	5.0	12.41	0.3	12.08	2.5
	10.0	12.58	1.6	12.42	4.5
SB-A: 16-19	2.5	12.20	1.2	12.35	1.5
	5.0	12.38	1.2	12.51	1.5
	10.0	12.62	1.3	12.67	4.2
SB-A: 24-27	2.5	11.96	1.0	11.51	1.6
	5.0	12.46	0.3	12.04	1.5
	10.0	12.65	0.6	12.39	3.9

Permanganate TOD

The soil/groundwater slurry was dosed at 2.5, 5.0, and 10.0 g/kg permanganate. The TOD was measured at 48 hours and 96 hours post treatment. The TOD was set up on September 30, 2013. The 48 hour permanganate TOD (TOD_{48Hr}) was measured on October 3, 2013 and the 96 hour (TOD_{96Hr}) on October 4, 2013.

At the 48 hour and 96 hour mark, the soil slurry was allowed to settle and an aliquot of the liquid fraction was decanted and analyzed for residual permanganate. Soil slurry TOD data is shown in Table 5. Results are discussed below.

1. The majority of the demand was observed in the first 48 hours and all of the permanganate was utilized within 96 hours.

2. It appears the permanganate more readily oxidizes the sample when compared to persulfate or the permanganate demand is greater than the persulfate demand. It si

not uncommon to observed high permanganate TOD in samples when they are treated with both permanganate and persulfate.

3. Permanganate TOD can be converted to potassium permanganate or sodium permanganate TOD by multiplying the permanganate TOD by 1.33 and 1.19, respectively.

Table 5.
TOD_{48} and TOD_{96} Results for Permanganate

		48 hour TOD	96 hour TOD
Sample ID	**Permanganate Dosage, g/kg**	**MnO_4, g/kg**	**MnO_4, g/kg**
SB-A: 10-11	2.5	> 2.5	> 2.5
	5.0	> 5.0	> 5.0
	10.0	> 10.0	> 10.0
SB-C: 20-21	2.5	> 2.5	> 2.5
	5.0	> 5.0	> 5.0
	10.0	> 10.0	> 10.0
SB-A: 30-33	2.5	> 2.5	> 2.5
	5.0	5.0	> 5.0
	10.0	10.0	> 10.0
SB-D: 30-33	2.5	> 2.5	> 2.5
	5.0	> 5.0	> 5.0
	10.0	> 10.0	> 10.0
SB-A: 16-19	2.5	> 2.5	> 2.5
	5.0	5.0	> 5.0
	10.0	9.8	> 10.0
SB-A: 24-27	2.5	> 2.5	> 2.5
	5.0	> 5.0	> 5.0
	10.0	10.0	> 10.0

TOD testing showed all of the permanganate was utilized within 96 hours. Persulfate testing showed either all persulfate was utilized or an increasing demand from 48 to 96 hours. Both cases suggest the oxidant demand was not met for all samples.

Effectiveness Testing Round 1 (102 Day Treatment – November 18, 2013 – February 28, 2014)

The TOD testing suggested that oxidant demand was higher than initial estimates. To better estimate the oxidant demand, a persulfate stoichiometric calculation was performed. Analytical data is shown for soil samples that have reported results (Table 6). Stoichiometric requirement and stoichiometric demand are shown in Table 7. The highest stoichiometric requirement was estimated to come from DRO, requiring an estimated 51.5 g of sodium persulfate/g of DRO (Table 7). The PCP stoichiometric requirement was estimated at 8.0 g of sodium persulfate/g of PCP. Stoichiometric demand estimates show the majority of the persulfate demand is expected to be from DRO and to a lesser degree residual hydrocarbons. Sample SB- A: 30-33 has the highest total stoichiometric demand at a calculate amount of 1,195 g persulfate/kg soil.

Table 6.
Soil Analytical Data

	mg/kg dry wt.			
Compound	SB-A: 16-19	SB-A: 24-27	SB-A: 30-33	SB-D: 30-33
DRO	3,000	13,000	22,000	2,000
Residual Range	170	660	1,200	1,500
PCP	1.1	110	15.0	530

Table 7.
Sodium Persulfate Soil Stoichiometric Demand

		Stoichiometric Demand, g Persulfate/kg Soil			
Compound	Stoichiometric Requirement, g Persulfate/g Compound	SB-A: 16-19	SB-A: 24-27	SB-A: 30-33	SB-D: 30-33
DRO (assume $C_{20}H_{42}$ as avg)	51.5	155	670	1,133	103
Residual Range (assume $C_{32}H_{60}$ as avg)	50.3	8.6	33	60	75
PCP	8.0	0.01	0.88	0.12	4.24
Est. Soil Oxidant Demand (SOD)	-	2.0	2.0	2.0	2.0
	Total	**165**	**706**	**1,195**	**185**

The objective of the study is to evaluate the effectiveness of persulfate and permanganate to reduce concentrations of PCP in soil. Therefore, a fifty percent reduction in PCP concentration was deemed acceptable.

The estimated stoichiometric demand as a percentage is shown in Table 8. To achieve a dosage of 50% of stoichiometric demand, 92 g persulfate/kg soil is required for sample SB-D: 30-33.

Table 8.
Sodium Persulfate as a Percentage of Soil Stoichiometric Demand

	g Persulfate/kg Soil			
Percent to Meet Stoichiometric Demand	SB-A: 16-19	SB-A: 24-27	SB-A: 30-33	SB-D: 30-33
100% of Stoic Demand	165	706	1,195	185
75% of Stoic Demand	124	529	897	139
50% of Stoic Demand	83	353	598	92
25% of Stoic Demand	41	176	299	46
10% of Stoic Demand	17	71	120	18

Two of the soil samples received were tested for the effectiveness testing phase of the study. The two samples tested were SB-A: 24-27 and SB-D: 30-33. The total target dosage tested were 25% and 50% of the stoichiometric demand. For sample SB-A: 24-27, the 25% stoichiometric total target dosage was 175 g persulfate/ kg of soil and 350 g persulfate/kg soil for 50% total target dosage. For sample SB-D: 30-33, the 25% stoichiometric total target dosage was 46 g persulfate/ kg of soil and 92 g persulfate/kg soil for 50% total target dosage. As earlier discussed, the permanganate stoichiometric demand was based on the persulfate demand. The initial dosage for SB-A: 24-27 was 43.8 g sodium permanganate/kg soil and 23 g sodium permanganate/kg soil for SB-D: 30-33. Addition permanganate dosages were based on the residual permanganate concentration, total dosage applied, and DRO and PCP results.

The test dosages used in the initial study well exceed the dosage that can be applied in one ISCO injection. This is due to the solubility of the oxidant and a mass that can be safely applied in the field. Therefore, multiple additions of chemical were applied over a period of 78 days to achieve the total target stoichiometric demand. An ISCO application of 12.5 mls of volume/50 g of soil is deemed acceptable for this site. This correlates to 60 gallons of liquid/ton of soil or 84 gallons of liquid/cubic yard, assuming a soil bulk density of 1.44 tons/cubic yard. Other factors such as soil lithology influence the volume of liquid that can be applied.

For persulfate treatment, activators are required. The amount and frequency of activator addition depends on the activator and the persulfate dosage. For example, persulfate forms sulfuric acid during decomposition. The amount of sulfuric acid formed is dependent on the persulfate addition and the decomposed amount of persulfate. To neutralize the sulfuric acid and maintain a pH of greater than 10.5, sodium hydroxide is required for each application. Hydrogen peroxide was added at a 1:1 molar ratio of hydrogen peroxide to persulfate at each application. Iron was only added during the initial application since iron will remain in the slurry and continue the reaction (catalyst). To maintain a pH range of 3 to 5 for effective iron persulfate activation, sulfuric acid is usually applied. In this study, no sulfuric acid was added at any application since more than enough sulfuric acid was formed from the decomposition of persulfate to maintain an acceptable pH level.

Table 10 shows the amount of oxidant and activator added for each application. For clarification, the persulfate dosage is only listed once per application in the table but each activated persulfate received the shown dosage plus activator. For example, in the first application for sample SB-A: 24-27 at the 25% stoichiometric target, alkaline persulfate was dosed with 43.8 g/kg persulfate and 16.8 g/kg NaOH. Peroxide activated persulfate for the same sample received 43.8 g/kg persulfate and 6.2 g/kg hydrogen peroxide.

Multiple oxidant applications were applied over a 78 day period. Sample SB-A: 24-27 received persulfate applications at Day 1, Day 22, Day 49, and Day 78 (Table 10). Sample SB-D: 30-33 received persulfate dosages at Day 1, Day 22, and Day 78 (Table 10). Note that three persulfate applications were applied for sample SB-D: 30-33. The three applications exceeded the target stoichiometric amounts of 46 and 92 g persulfate /kg soil. The actual stoichiometric amount of persulfate added to sample SB-D: 30-33 was 69 g/kg persulfate and 115 g/kg persulfate which correlates to 37% and 62% of the total stoichiometric demand, respectively. Permanganate was applied Day 1and Day 78 (Table 10). Sample SB-A: 24-27 received 43.8 g/kg permanganate on Day 1 and Day 78 for a total of 82.6 g/kg. Sample SB-D: 30-33 received 23 g/kg permanganate on Day 1 and 46 g/kg permanganate Day 78 for a total of 69 g/kg.

Table 10.
Effectiveness Testing Round 1 - Oxidant Dosage Application

Application	Chemical/Dosage	SB-A: 24-27		SB-D: 30-33	
	Stoichiometric Target	25%	50%	25%	50%
	Total Target Dosage, g/kg	175	350	46	92
1st Application - 11/18/13 (Day 1)	Persulfate Dosage, g/kg	43.8	87.5	23	46
	NaOH Dosage, g/kg	16.8	32.1	10.6	18.6
	Hydrogen Peroxide, g/kg	6.2	12.5	3.3	6.6
	Iron, mg/kg	300	300	300	300
	Sodium Permanganate, g/kg	43.8	NA	23	NA
2nd Application 12/10/13 (Day 22)	Persulfate Dosage, g/kg	43.8	87.5	23	46
	NaOH Dosage, g/kg	15.3	30.6	8.1	16.1
	Hydrogen Peroxide, g/kg	6.2	12.5	3.3	6.6
	Iron, mg/kg	NA	NA	NA	NA
	Sodium Permanganate, g/kg	NA	NA	NA	NA
3rd Application 1/6/14 (Day 49)	Persulfate Dosage, g/kg	43.8	87.5	NA	NA
	NaOH Dosage, g/kg	15.3	30.6	NA	NA
	Hydrogen Peroxide, g/kg	6.2	12.5	3.3	6.6
	Iron, mg/kg	NA	NA	NA	NA
	Sodium Permanganate, g/kg	NA	NA	NA	NA
4th Application 2/4/14 (Day 78)	Persulfate Dosage, g/kg	43.8	87.5	23	23
	NaOH Dosage, g/kg	15.3	30.6	8.1	8.1
	Hydrogen Peroxide, g/kg	6.2	12.5	3.3	6.6
	Iron, mg/kg	NA	NA	NA	NA
	Sodium Permanganate, g/kg	43.8	NA	46	NA
Total	Persulfate Dosage, g/kg	175	350	69	115
	NaOH Dosage, g/kg	63	124	27	43
	Hydrogen Peroxide, g/kg	24.8	50	9.9	19.8
	Iron, mg/kg	300	300	300	300
	Sodium Permanganate, g/kg	87.6	NA	69	NA

NA = Not applied

Various analytical tests were performed depending on the application day. On Day 22, and Day 79, pH, TOD, and residual oxidant were measured. On Day 49 and Day 102, pH, TOD, residual oxidant, arsenic, total chromium, copper, lead, DRO, and PCP were measured. If analytical testing and oxidant addition fell on the same day, analytical testing was performed prior to adding additional oxidant. Data for sample SB-A: 24-27 is shown in Table 11. Data for sample SB-D: 30-33 is shown in Table 12.

Table 11.
Effectiveness Testing Round 1 - Analytical Data for Sample SB-A: 24-27

SB-A: 24-27									
Test Day	Test/Units	Control	Alkaline Persulfate		Peroxide Persulfate		Iron Persulfate		Permanganate
Day 22	Total Dosage g/kg	NA	23.0	46.0	23.0	46.0	23.0	46.0	23.0
	pH	NA	10.30	13.49	3.50	2.70	2.66	2.42	NA
	TOD, g/kg	NA	19.9	35.6	19.1	26.7	19.2	26.4	6.6
	Residual Oxidant, g/kg	NA	3.1	10.4	3.9	19.3	3.8	19.6	16.4
Day 49	Total Dosage g/kg	NA	46.0	92.0	46.0	92.0	46.0	92.0	23.0
	pH	NA	12.19	12.75	2.45	2.18	2.40	2.18	NA
	TOD, g/kg	NA	39.2	55.9	37.9	50.7	38.1	51.7	11.5
	Residual Oxidant, g/kg	NA	6.8	36.1	8.1	41.3	7.9	40.3	11.5
	As, mg/L	<0.30	0.94	1.14	<0.30	<0.30	<0.30	<0.30	<3.0
	Cr (total), mg/L	<0.050	0.92	1.94	0.36	1.07	0.34	0.66	3.50
	Cu, mg/L	<0.050	0.060	0.073	1.44	2.92	1.60	2.52	1.14
	Pb, mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	0.31	<3.0
	DRO, mg/kg	12,000	11,000	12,000	11,000	8,600	13,000	8,000	15,000
	DRO, % Reduction	-	8%	0%	8%	28%	-8%	33%	-25%
	PCP, mg/kg	190	5.8	4.8	110	150	80	48	58
	PCP, % Reduction	-	97%	97%	42%	21%	58%	75%	69%

Table 11 (Cont.).
Effectiveness Testing Round 1 - Analytical Data for Sample SB-A: 24-27

SB-A: 24-27									
Test Day	Test/Units	Control	Alkaline Persulfate		Peroxide Persulfate		Iron Persulfate		Permanganate
Day 78	Total Dosage g/kg	NA	46.0	92.0	46.0	92.0	46.0	92.0	23.0
	pH	6.30	10.64	12.90	2.47	2.38	2.42	2.29	8.96
	TOD, g/kg	NA	38.7	52.7	37.4	47.9	37.4	47.5	>23.0
	Residual Oxidant, g/kg	NA	7.3	39.3	8.6	44.1	8.6	44.5	0.0
Day 102	Total Dosage g/kg	NA	69.0	115.0	69.0	115.0	69.0	115.0	69.0
	pH	NA	12.87	13.13	2.43	2.33	2.35	2.27	8.89
	TOD, g/kg	NA	58.5	59.5	56.6	52.3	56.8	52.7	39.1
	Residual Oxidant, g/kg	NA	10.5	55.5	12.4	62.7	12.2	62.3	29.9
	As, mg/L	<0.30	0.80	0.90	<0.30	<0.30	<0.30	<0.30	0.33
	Cr (total), mg/L	<0.050	0.90	1.17	1.04	1.64	0.81	1.26	2.23
	Cu, mg/L	<0.050	<0.050	<0.05	2.21	2.87	2.10	2.61	<0.050
	Pb, mg/L	<0.30	<0.30	<0.30	<0.30	0.41	<0.30	<0.30	0.93
	DRO, mg/kg	13,000	9,700	13,000	11,000	5,200	8,200	5,000	6,400
	DRO, % Reduction	-	25%	0%	15%	60%	37%	62%	51%
	PCP, mg/kg	130	4.6	<3.8	51	27	63	30	31
	PCP, % Reduction	-	96%	>97%	61%	79%	52%	77%	76%

Table 12.
Effectiveness Testing Round 1 - Analytical Data for Sample SB-D: 30-33

SB-D: 30-33									
Test Day	Test/Units	Control	Alkaline Persulfate		Peroxide Persulfate		Iron Persulfate		Permanganate
Day 22	Total Dosage g/kg	NA	23.0	46.0	23.0	46.0	23.0	46.0	23.0
	pH	NA	10.30	13.49	3.50	2.70	2.66	2.42	NA
	TOD, g/kg	NA	19.9	35.6	19.1	26.7	19.2	26.4	6.6
	Residual Oxidant, g/kg	NA	3.1	10.4	3.9	19.3	3.8	19.6	16.4
Day 49	Total Dosage g/kg	NA	46.0	92.0	46.0	92.0	46.0	92.0	23.0
	pH	NA	12.19	12.75	2.45	2.18	2.40	2.18	NA
	TOD, g/kg	NA	39.2	55.9	37.9	50.7	38.1	51.7	11.5
	Residual Oxidant, g/kg	NA	6.8	36.1	8.1	41.3	7.9	40.3	11.5
	As, mg/L	<0.30	0.94	1.14	<0.30	<0.30	<0.30	<0.30	<3.0
	Cr (total), mg/L	<0.050	0.92	1.94	0.36	1.07	0.34	0.66	3.50
	Cu, mg/L	<0.050	0.060	0.073	1.44	2.92	1.60	2.52	1.14
	Pb, mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	0.31	<3.0
	DRO, mg/kg	12,000	11,000	12,000	11,000	8,600	13,000	8,000	15,000
	DRO, % Reduction	-	8%	0%	8%	28%	-8%	33%	-25%
	PCP, mg/kg	190	5.8	4.8	110	150	80	48	58
	PCP, % Reduction	-	97%	97%	42%	21%	58%	75%	69%
Day 78	Total Dosage g/kg	NA	46.0	92.0	46.0	92.0	46.0	92.0	23.0
	pH	6.30	10.64	12.90	2.47	2.38	2.42	2.29	8.96
	TOD, g/kg	NA	38.7	52.7	37.4	47.9	37.4	47.5	>23.0
	Residual Oxidant, g/kg	NA	7.3	39.3	8.6	44.1	8.6	44.5	0.0

Table 12 (Cont.).
Effectiveness Testing Round 1 - Analytical Data for Sample SB-D: 30-33

SB-D: 30-33									
Test Day	Test/Units	Control	Alkaline Persulfate		Peroxide Persulfate		Iron Persulfate		Permanganate
Day 102	Total Dosage g/kg	NA	69.0	115.0	69.0	115.0	69.0	115.0	69.0
	pH	NA	12.87	13.13	2.43	2.33	2.35	2.27	8.89
	TOD, g/kg	NA	58.5	59.5	56.6	52.3	56.8	52.7	39.1
	Residual Oxidant, g/kg	NA	10.5	55.5	12.4	62.7	12.2	62.3	29.9
	As, mg/L	<0.30	0.80	0.90	<0.30	<0.30	<0.30	<0.30	0.33
	Cr (total), mg/L	<0.050	0.90	1.17	1.04	1.64	0.81	1.26	2.23
	Cu, mg/L	<0.050	<0.050	<0.05	2.21	2.87	2.10	2.61	<0.050
	Pb, mg/L	<0.30	<0.30	<0.30	<0.30	0.41	<0.30	<0.30	0.93
	DRO, mg/kg	13,000	9,700	13,000	11,000	5,200	8,200	5,000	6,400
	DRO, % Reduction	-	25%	0%	15%	60%	37%	62%	51%
	PCP, mg/kg	130	4.6	<3.8	51	27	63	30	31
	PCP, % Reduction	-	96%	>97%	61%	79%	52%	77%	76%

TOD results between activated persulfate chemistries were consistent throughout the study. Comparing the three activated persulfate chemistries at the same dosage shows alkaline activated persulfate TOD to be slightly higher than peroxide and iron activated persulfate. For example, at Day 22, sample SB-A: 24-27, 43.8 g/kg persulfate dosage found a TOD of alkaline persulfate of 36.6 g/kg, 27.5 g/kg for peroxide persulfate and 27.5 for iron persulfate (Table 11). A slightly higher alkaline activated persulfate was observed for all SB-A: 24-27 test days and dosage levels. Sample SB-D: 30-33 showed consistent TOD results for peroxide and iron activated persulfate. Alkaline activated persulfate also showed a slightly higher TOD at each test day and dosage when compared to peroxide and iron activated persulfate (Table 12).

Higher TOD results were observed with higher persulfate dosages. This was found for each sample and every dosage (Tables 11 and 12). This is a typically observed with persulfate.

A majority of permanganate was used within 49 days for sample SB-A: 24-27 (Table 11). Permanganate was dosed at 43.8 g/kg sodium permanganate and after 49 days, the TOD was 41.3 g/kg (2.5 g/kg residual). Sample SB-D: 30-33 was dosed at 23 g/kg sodium permanganate and all of the permanganate was spent after 78 days (Table 12).

The pH levels were in excess of 10.5 for all alkaline activated persulfate dosages except Day 22 for sample SB-D: 30-33, 23 g/kg dosage (Table 12). The pH was 10.30, which is not unexpected since most of the persulfate was used and the formation of sulfuric acid almost complete. Therefore, neutralizing most of the NaOH added. Peroxide and iron activated persulfate each showed pH levels of 3.50 or less throughout the study (Tables 11 and 12). As discussed earlier, this was anticipated due to the large persulfate dosages and subsequent large amount of sulfuric acid formed.

Dissolved metals analysis was conducted at Day 49 and 102. Alkaline activated persulfate showed increased arsenic and chromium concentrations for samples SB-A: 24-27 and SB-D: 30-33 when compared to their respective control (Tables 11 and 12). While peroxide and iron activated persulfate showed no arsenic mobilization in either sample. Chromium and copper concentrations were higher in the peroxide and iron activation with no mobilization of copper in alkaline activation (Tables 11 and 12). Permanganate showed no mobilization of arsenic and lead while chromium and copper was observed in samples SB-A: 24-27 and SB-D: 30-33 (Tables 11 and 12). Depending on the chemistry and dosage, metal mobilization was observed.

Persulfate dosages where based on stoichiometric demand of the samples. Stoichiometric calculations showed the majority of the demand is from DRO (Table 7). Samples were treated at 25% (175 g persulfate/kg soil) and 50% (350 g persulfate/kg soil) of total stoichiometric demand for sample SB-A: 24-27. For sample SB-D: 30-33, 37% (69 g persulfate/kg soil) and 62% (115 g persulfate/kg soil) was applied. A total permanganate dosage of 87.6 g sodium permanganate/kg soil was added to sample SB-A: 24-27 and 69.0

g sodium permanganate/kg soil to sample SB-D: 30-33. A breakdown of oxidant and activator added for each application is shown in Table 10.

DRO and PCP testing was conducted on Day 49 and 102. Total activated persulfate dosages at Day 49 for sample SB-A: 24-27 were 87.5 g persulfate/kg soil (12% of total stoichiometric requirement) and 175 g persulfate/kg soil (25% of total stoichiometric requirement). At day 102, sample SB-A: 24-27 received 175 g/kg persulfate (25% of total stoichiometric requirement) and 350 g/kg persulfate (50% of total stoichiometric requirement). Sodium permanganate dosages for sample SB-A: 24-27 was 43.8 g/kg at Day 49 and 87.6 g/kg at day 102.

Total activated persulfate dosages at Day 49 for sample SB-D: 30-33 were 46.0 g persulfate/kg soil (25% of total stoichiometric requirement) and 92.0 g persulfate/kg soil (50% of total stoichiometric requirement). By day 102, sample SB-D: 30-33 had received 69.0 g/kg persulfate (37% of total stoichiometric requirement) and 115 g/kg persulfate (62% of total stoichiometric requirement).

Sodium permanganate dosages for sample SB-D: 30-33 were 23 g/kg at Day 49 and 69.0 g/kg at day 102.

Comparing the control to the treated samples shows some variability in DRO concentration reduction for samples SB-A: 24-27 and SB-D: 30-33. No significant reduction in DRO concentration was observed for sample SB-A: 24-27 (Table 11) and SB-D: 30-33 (Table 12) at Day 49 regardless of oxidant and dosage. Although some dosages and oxidant showed a reduction in DRO levels, there is enough variability in the data not to show equivocally a net reduction. Data from Day 102 shows no significant difference between the control and persulfate treated SB-A: 24-27 samples (Table 11). Sample SB-D: 30-33 peroxide and iron activated persulfate treatments dosages suggest a slight reduction in DRO concentrations (Table 12). No apparent DRO reduction was observed with alkaline activation in sample SB-D: 30-33. A permanganate dosage of 69.0 g sodium permanganate /kg soil did show a reduction in DRO when compared to the control, but based on the ineffectiveness of permanganate to mineralize petroleum hydrocarbons, the perceived reduction is attributed to variability.

Based on the DRO data, TOD, and residual oxidant, activated persulfate does not appear effective in lowering DRO concentrations when dosages as high at 62% of the sample stoichiometric demand are tested.

Significant PCP concentration reduction was observed with all activated persulfate chemistries and permanganate. PCP concentration in the control SB-A: 24-27 at Day 49 was 45 mg/kg. Alkaline persulfate treatment at 87.5 and 175 g persulfate/kg soil found PCP concentrations of 3.6 mg/kg and 2.2 mg/kg, respectively (Table 11). These dosages correlate to 12% and 25% of the total stoichiometric requirement. Peroxide and iron activated persulfate also showed significant PCP reductions at Day 49 (Table 11).

Peroxide activation found 14 mg/kg PCP at the 87.5 g persulfate/kg soil dosage and 12 mg/kg PCP at the 175 g persulfate/kg soil. Iron activated persulfate found similar results to the peroxide activated persulfate. At the 87.5 g persulfate/kg soil dosage, 11 mg/kg PCP was reported and 13 mg/kg PCP at the 175 g persulfate/kg soil dosage. Permanganate also effectively reduced the PCP concentration. At a permanganate dosage of 43.8 g sodium permanganate/kg soil, 4.8 mg/kg PCP was reported (Table 11).

At Day 102 and persulfate dosages of 175 and 350 g persulfate/kg soil, significant PCP was observed. Comparing the control SB-A: 24-27 PCP concentration of 31 mg/kg to the persulfate activated treatments found alkaline activated persulfate PCP concentration below detection limit for both dosages (Table 11). Peroxide activation found 7.3 mg/kg PCP at the 175 g persulfate/kg soil dosage and 7.4 mg/kg PCP at the 350 g persulfate/kg soil. Iron activated persulfate found similar results to the peroxide activated persulfate. Peroxide activated persulfate found 7.3 mg/kg PCP at the 175 g persulfate/kg soil dosage and 7.4 mg/kg PCP at the 350 g persulfate/kg soil dosage. Iron activated persulfate found 8.6 mg/kg PCP at the 175 g persulfate/kg soil dosage and 11 mg/kg PCP at the 350 g persulfate/kg soil dosage. At a permanganate dosage of 87.6 g sodium permanganate/kg soil, <3.3 mg/kg PCP was reported (Table 11). A comparison between the Day 49 175 g persulfate/kg soil dosage to Day 102 175 g persulfate/kg soil dosage can be made. Comparing the data shows Day 49 175 g persulfate/kg soil dosage PCP concentration of 2.2 mg/L and Day 102 175 g persulfate/kg soil dosage PCP concentration of <4.7 mg/kg. Essentially, the majority of the PCP is treated. This data would suggest that the alkaline persulfate PCP reaction is complete within 49 days at the dosages applied. Comparing the peroxide and iron activated PCP data for the same dosage and days may not suggest a complete reaction (Table 11).

Effective PCP treatment was also found in Sample SB-D: 30-33 when treated with activated persulfate and permanganate. The SB-D: 30-33 control concentration of 190 mg/kg PCP is roughly four times higher than the SB-A: 24-27 sample and the dosage levels applied in SB-D: 30-33 are less than that applied for SB-A: 24-27. Although the PCP concentration is higher and the treatment dosages lower, significant PCP reduction was observed at Day 49 and Day 102. Alkaline persulfate treatment at 46 and 92 g persulfate/kg soil found PCP concentrations of 5.8 mg/kg and 4.8 mg/kg, respectively (Table 12). These dosages correlate to 25% and 50% of the total stoichiometric requirement. Peroxide and iron activated persulfate also showed PCP reductions at Day 49, although iron activation appears to be more effective than peroxide activated (Table 12). Peroxide activation found 110 mg/kg PCP at the 46 g persulfate/kg soil dosage and 150 mg/kg PCP at the 92 g persulfate/kg soil. Iron activated persulfate found lower results to the peroxide activated persulfate. At the 46 g persulfate/kg soil dosage, 80 mg/kg PCP was reported and 48 mg/kg PCP at the 92 g persulfate/kg soil dosage. Permanganate also effectively reduced the PCP concentration. At a permanganate dosage of 23 g sodium permanganate/kg soil, 58 mg/kg PCP was reported (Table 12).

At Day 102 and persulfate dosages of 69 and 115 g persulfate/kg soil, significant PCP was observed. Comparing the control SB-A: 24-27 PCP concentration of 130 mg/kg to the persulfate activated treatments found alkaline activated persulfate PCP concentration of 4.6 mg/kg for the 69 g persulfate/g soil dosage and <3.8 mg/kg PCP for the 115 g persulfate/kg soil dosage (Table 12). Peroxide activation found 51 mg/kg PCP at the 69 g persulfate/kg soil dosage and 27 mg/kg PCP at the 115 g persulfate/kg soil. Iron activated persulfate found similar results to the peroxide activated persulfate. Iron activated persulfate found 63 mg/kg PCP at the 69 g persulfate/kg soil dosage and 30 mg/kg PCP at the 115 g persulfate/kg soil dosage. At a permanganate dosage of 69 g sodium permanganate/kg soil, 31 mg/kg PCP was reported (Table 12).

Based on this study, a 97% PCP reduction or greater can be achieved with alkaline activated persulfate. An alkaline activated dosage rate as low as 87.5 g persulfate/kg soil reduced the PCP concentration to 3.6 mg/kg PCP in SB-A: 24-27. An alkaline activated persulfate dosage of 46 g persulfate/kg reduced PCP to 3.6 mg/kg in SB-D: 30-33. Higher dosages and longer reaction times did not significantly improve the performance of alkaline activate persulfate. Peroxide and iron activated persulfate also reduced PCP concentrations but not as effectively as alkaline activated persulfate. Residual persulfate was found at each dosage and each test date. The residual persulfate concentration was dependent on the dosage applied and/or the date analyzed. In general, higher residual persulfate concentrations were observed with higher dosages. Significant reduction in PCP concentrations was observed within 49 days. Additional persulfate and longer reaction times resulted in higher persulfate demands but no additional significant reduction of PCP. This would suggest that kinetics of the PCP alkaline persulfate reaction is faster than the reaction of persulfate with other compounds in the soil and groundwater. Therefore, lower dosages and shorter reactions times can be applied which will decrease field implementation and lower oxidant costs.

Permanganate was effective in reducing PCP concentrations at 87.6 g sodium permanganate/kg soil.

<u>Effectiveness Testing Round 2 (49 Day Treatment – June 26 – August 14, 2014)</u>

Round 1 testing showed alkaline activated persulfate to be more effective in reducing PCP concentrations than either peroxide activated persulfate, iron activated persulfate and permanganate. Round 1 testing at 49 days found alkaline activated persulfate significantly reduced PCP concentrations and found measurable concentrations of residual persulfate – suggesting that a shorter reaction time and lower persulfate dosage is feasible.. A second round of testing was conducted where the alkaline activated persulfate dosages were reduced with a treatment period of 49 days.

Round 1 testing showed alkaline activated persulfate dosages of up to 46.0 g persulfate/kg reduced PCP concentration of greater than 97% within 49 days and had measureable residual persulfate. Round 2 testing was conducted with alkaline activated persulfate at doses lower than 46.0 g persulfate/kg soil.

Alkaline activated persulfate dosages of 8 g persulfate/kg , 16 g persulfate/kg, and 23 g persulfate/kg soil where allowed to react for 49 days for samples SB-A: 24-27 and SB-D: 30-33 in Round 2. Dosages for each sample are shown in Table 13, including the sodium hydroxide dosages required to maintain a pH of > 10.5. After 49 days, the samples were analyzed for residual persulfate, pH, PCP and DRO. Results for sample SB-A: 24-27 are shown in Table 14 and Table 15 for SB-D: 30-33.

Table 13.
Effectiveness Testing Round 2 - Oxidant Dosage Application

Application	Chemical/Dosage	SB-A: 24-27			SB-D: 30-33		
Application - 6/26/2014 (Day 1)	Persulfate Dosage, g/kg	8.0	16.0	23.0	8.0	16.0	23.0
	NaOH Dosage, g/kg	4.2	7.0	9.5	5.3	8.1	10.6

Table 14.
Effectiveness Testing Round 2 - Analytical Data for Sample SB-A: 24-27

	SB-A: 24-27 (Day 49)							
Sample ID	Control		Alkaline Persulfate					
Dosage g/kg	NA	DUP	8.0	8.0 DUP	16.0	16.0 DUP	23.0	23.0 DUP
pH	NA	NA	9.28	NA	9.34	NA	9.59	NA
TOD, g/kg	NA	NA	6.8	NA	13.8	NA	19.8	NA
Residual Oxidant, g/kg	NA	NA	1.2	NA	2.2	NA	3.2	NA
DRO, mg/kg	10,000	NA	9,800	NA	8,900	NA	11,000	NA
DRO, % Reduction	-	-	2%	NA	11%	NA	-10%	NA
PCP, mg/kg	19	9.9	7.4	7.5	6.2	8.2	8.4	7.7
PCP, % Reduction	-	-	49%	48%	57%	43%	42%	47%

Table 15.
Effectiveness Testing Round 2 - Analytical Data for Sample SB-D: 30-33

	SB-D: 30-33 (Day 49)							
Sample ID	Control		Alkaline Persulfate					
Dosage g/kg	NA	DUP	8.0	8.0 DUP	16.0	16.0 DUP	23.0	23.0 DUP
pH	NA	NA	10.30	NA	10.02	NA	10.11	NA
TOD, g/kg	NA	NA	> 8	NA	15.0	NA	20.8	NA
Residual Oxidant, g/kg	NA	NA	ND	NA	1.0	NA	2.2	NA
DRO, mg/kg	12,000	NA	14,000	NA	14,000	NA	15,000	NA
DRO, % Reduction	-	-	-17%	NA	-17%	NA	-25%	NA
PCP, mg/kg	18	22	26	26	20	6.2	9.0	6.3
PCP, % Reduction	-	-	-30%	-30%	0%	69%	55%	69%

The pH for each sample and dosage was slightly lower than the target pH of > 10.5. Although, most if not all of the persulfate was spent in the samples, therefore the pH was expected to be lower. As found in Round 1 testing, the higher the persulfate dosage the higher the TOD result. At 49 days post treatment, little if any persulfate remained in the samples regardless of dosage.

The DRO Control concentration for sample SB-A: 24-27 was 10,000 mg/kg (Table 14). This is slightly higher than the control at 49 days in Round 1 for the same sample (7,200 mg/kg). DRO concentration for sample SB-D: 30-33 control was identical for Round 1 and Round 2 testing of 12,000 mg/kg DRO (Table 12 and Table 15). No apparent reduction in DRO concentrations was observed in either SB-A: 24-27 or SB-D: 30-33 at the dosages tested in Round 2. This is consistent with Round 1 testing where there was not conclusive evidence for DRO reduction.

Control PCP concentrations were lower in Round 2 than Round 1 for both samples. Sample SB-A: 24-27 Round 1 control sample at 49 days found a PCP concentration of 45 mg/kg (Table 11) and a Round 2 control concentration of 19 mg/kg and 9.9 mg/kg in the sample duplicate (Table 14). SB-D: 30-33 showed significantly lower concentrations in the Round 2 control than the Round 1 control. Round 2 control found 18 mg/kg PCP in the sample and 18 mg/kg in the sample duplicate (Table 15). Round 1 control had found 190 mg/kg PCP (Table 12). The SB-D: 30-33 control sample was re-extracted and reanalyzed to confirm the PCP concentration. A reanalysis result of 22 mg/kg PCP was found (reanalysis data not shown in Table 14). Unlike the DRO concentrations which found consistency between rounds, PCP concentrations were lower in Round 2 controls than in Round 1 controls. Round 2 sub-samples were taken from a different sample jar than the soil used in Round 1 testing. Variability within the sample jars may explain the differences observed between Round 1 and Round 2 PCP concentrations.

PCP reduction was not as evident in Round 2 testing as Round 1 testing. This was anticipated since the objective was to lower persulfate dosages with the goal of obtaining a minimum dosage that can significantly reduce PCP concentrations. Round 1 found PCP reductions of greater than 97% for both samples while Round 2 varied between 42 to 57% reduction for sample SB-A: 24-27 and 0 to 69% reduction for sample SB-D: 30-33. For sample SB-A: 24-27, no significant difference was observed between the each dosage tested and the control (Table 14). The 8 g persulfate/kg dosage performed as well as the 16 g persulfate/kg and 23 g persulfate/kg sample. Sample SB-D: 30-33 did show an effectiveness difference between dosages (Table 15). The 8 g persulfate/kg dosage and one of the 16 g persulfate/kg results showed no PCP reduction. In fact, the reported results were higher than the control value. The 23 g persulfate/kg dosage found a 55 and 69% reduction in PCP levels.

SUMMARY/DISCUSSION

Alkaline, peroxide, and iron activated sodium persulfate, and permanganate chemistries were tested to measure reductions of DRO and PCP concentrations in soil and groundwater slurries. The objective was to lower PCP levels.

TOD testing was conducted prior to effectiveness testing to determine the demand for the chemistries and to assist in defining dosages for effectiveness testing. The TOD found inconclusive data to set the effectiveness dosages. Therefore, Round 1 dosages where based on calculations to estimate potential stoichiometric demand due to DRO.

Round 1effectiveness testing was performed on the two slurry samples using the defined oxidants. A 97% PCP reduction or greater can be achieved with alkaline activated persulfate in the doses employed during Round 1. An alkaline activated dosage rate as low as 43.8 g persulfate/kg soil reduced the PCP concentration to 3.6 mg/kg PCP in SB-A: 24-27 at 49 days treatment. An alkaline activated persulfate dosage of 46 g persulfate/kg reduced PCP to 4.8 mg/kg in SB-D: 30-33 at 49 days treatment. In both cases, significant amounts of residual persulfate remained during Round 1. Higher dosages and longer reactive times did not significantly improve the performance of alkaline activate persulfate. Peroxide and iron activated persulfate also reduced PCP concentrations but not as effectively as alkaline activated persulfate. Permanganate was effective in reducing PCP concentrations at 87.6 g sodium permanganate/kg soil.

During Round 2 effectiveness testing, lower persulfate dosages where tested to measure the limits of PCP treatment effectiveness. Dosages of 8 g persulfate/kg, 16 g persulfate/kg, and 23 g persulfate/kg found lower treatment effectiveness than dosages near 45 g persulfate/kg. PCP concentration reduction of up to 69% was achieved within 49 days with no significant residual persulfate remaining at the Round 2 dosages.

Dosages where based on stoichiometric demand of DRO, residual hydrocarbons, and PCP concentrations. Stoichiometric calculations found most of the demand from DRO. It was assumed that persulfate would react with DRO, residual hydrocarbons, and PCP equally. This study found significant reduction in PCP concentrations while little if any reduction in

DRO concentrations. This shows alkaline persulfate is preferentially treating PCP over DRO and residual hydrocarbons.

REFERENCES

Haselow, J, S., Siegrist, R, L., Crimi, M., and Jarosch, T. 2003. Estimating the Total Oxidant Demand for In Situ Chemical Oxidation Design. Remediation Autumn 2003

Sincerely,

Andrew Wenzel
Principal

APPENDIX A – CT Laboratory Analytical Report
Round 1 Data Set 1

Ursus Remediation Testing & Technologies LLC

200 E Lincoln Street
Mount Horeb, WI 53572
(608) 437-7413

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ANALYTICAL REPORT

URSUS REMEDIATION TESTING & TE
ANDREW WENZEL
1412 MANOR DRIVE
MOUNT HOREB, WI 53572

Project Name: AMEC - JH BAXTER
Project Phase:
Contract #: 2089
Project #:
Folder #: 102095
Purchase Order #:

Arrival Temperature: See COC
Report Date: 01/27/2014
Date Received: 01/08/2014
Reprint Date: 01/27/2014

CT LAB Sample#: 417129 Sample Description: SB-D-30-33 CONTROL Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**70.3**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**12000**	mg/kg	510	1700	10	M	01/09/2014 14:00	01/23/2014 21:02	JJY	EPA 8015C
Pentachlorophenol	**190**	mg/kg	13	45	20		01/09/2014 14:00	01/13/2014 18:16	RPN	EPA 8270D

CT LAB Sample#: 417130 Sample Description: SB-D-30-33 ALK PERS 46 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**68.9**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**11000**	mg/kg	520	1700	10		01/09/2014 14:00	01/23/2014 11:30	JJY	EPA 8015C
Pentachlorophenol	**5.8**	mg/kg	3.5 *	12	5		01/09/2014 14:00	01/17/2014 11:29	RPN	EPA 8270D

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Page 2 of 8

CT LAB Sample#: 417131 Sample Description: SB-D-30-33 ALK PERS 92 Sampled: 01/08/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**66.7**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**12000**	mg/kg	540	1800	10		01/09/2014 14:00	01/23/2014 12:03	JJY	EPA 8015C
Pentachlorophenol	**4.8**	mg/kg	1.4	4.8	2		01/09/2014 14:00	01/17/2014 11:48	RPN	EPA 8270D

CT LAB Sample#: 417132 Sample Description: SB-D-30-33 H2O2 PERS 46 Sampled: 01/08/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**69.3**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**11000**	mg/kg	510	1700	10		01/09/2014 14:00	01/23/2014 12:36	JJY	EPA 8015C
Pentachlorophenol	**110**	mg/kg	17	58	25		01/09/2014 14:00	01/17/2014 10:52	RPN	EPA 8270D

CT LAB Sample#: 417133 Sample Description: SB-D-30-33 H2O2 PERS 92 Sampled: 01/08/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**67.7**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										

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Page 3 of 8

CT LAB Sample#: 417133 Sample Description: SB-D-30-33 H2O2 PERS 92 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Diesel Range Organics	8600	mg/kg	530	1700	10		01/09/2014 14:00	01/23/2014 13:09	JJY	EPA 8015C
Pentachlorophenol	150	mg/kg	7.1	24	10		01/09/2014 14:00	01/13/2014 22:08	RPN	EPA 8270D

CT LAB Sample#: 417134 Sample Description: SB-D-30-33 FE PERS 46 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	68.9	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	13000	mg/kg	520	1700	10		01/09/2014 14:00	01/23/2014 13:42	JJY	EPA 8015C
Pentachlorophenol	80	mg/kg	6.9	23	10		01/09/2014 14:00	01/13/2014 22:32	RPN	EPA 8270D

CT LAB Sample#: 417135 Sample Description: SB-D-30-33 FE PERS 92 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	68.6	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	8000	mg/kg	520	1700	10		01/09/2014 14:00	01/23/2014 14:16	JJY	EPA 8015C
Pentachlorophenol	48	mg/kg	3.5	12	5		01/09/2014 14:00	01/13/2014 20:34	RPN	EPA 8270D

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Page 4 of 8

CT LAB Sample#: 417136 Sample Description: SB-D-30-33 PERM 23 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**70.3**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**15000**	mg/kg	510	1700	10		01/09/2014 14:00	01/23/2014 14:49	JJY	EPA 8015C
Pentachlorophenol	**58**	mg/kg	13	45	20		01/09/2014 14:00	01/17/2014 11:10	RPN	EPA 8270D

CT LAB Sample#: 417137 Sample Description: SB-A-24-27 CONTROL Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**72.7**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**7200**	mg/kg	500	1600	10		01/09/2014 14:00	01/23/2014 15:23	JJY	EPA 8015C
Pentachlorophenol	**45**	mg/kg	6.5	22	10	M	01/09/2014 14:00	01/17/2014 12:27	RPN	EPA 8270D

CT LAB Sample#: 417138 Sample Description: SB-A-24-27 ALK PERS 87.5 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**69.2**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										

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CT LAB Sample#: 417138 Sample Description: SB-A-24-27 ALK PERS 87.5 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Diesel Range Organics	**9200**	mg/kg	520	1700	10		01/09/2014 14:00	01/23/2014 15:56	JJY	EPA 8015C
Pentachlorophenol	**3.6**	mg/kg	0.69	2.3	1		01/09/2014 14:00	01/13/2014 15:10	RPN	EPA 8270D

CT LAB Sample#: 417139 Sample Description: SB-A-24-27 ALK PERS 175 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**65.7**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**11000**	mg/kg	540	1800	10		01/09/2014 14:00	01/23/2014 16:30	JJY	EPA 8015C
Pentachlorophenol	**2.2**	mg/kg	0.74 *	2.5	1		01/09/2014 14:00	01/13/2014 14:50	RPN	EPA 8270D

CT LAB Sample#: 417140 Sample Description: SB-A-24-27 H2O2 PERS 87.5 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**75.9**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**7600**	mg/kg	470	1500	10		01/09/2014 14:00	01/23/2014 18:12	JJY	EPA 8015C
Pentachlorophenol	**14**	mg/kg	6.3 *	21	10		01/09/2014 14:00	01/17/2014 12:09	RPN	EPA 8270D

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CT LAB Sample#: 417141 Sample Description: SB-A-24-27 H2O2 PERS 175 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**74.4**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**6200**	mg/kg	480	1600	10		01/09/2014 14:00	01/23/2014 18:46	JJY	EPA 8015C
Pentachlorophenol	**12**	mg/kg	1.3	4.3	2		01/09/2014 14:00	01/13/2014 19:01	RPN	EPA 8270D

CT LAB Sample#: 417142 Sample Description: SB-A-24-27 FE PERS 87.5 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**70.8**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**6100**	mg/kg	510	1700	10		01/09/2014 14:00	01/23/2014 19:20	JJY	EPA 8015C
Pentachlorophenol	**11**	mg/kg	1.4	4.6	2		01/09/2014 14:00	01/13/2014 19:24	RPN	EPA 8270D

CT LAB Sample#: 417143 Sample Description: SB-A-24-27 FE PERS 175 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**70.5**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										

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CT LAB Sample#: 417143 Sample Description: SB-A-24-27 FE PERS 175 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Diesel Range Organics	**6100**	mg/kg	510	1700	10		01/09/2014 14:00	01/23/2014 19:54	JJY	EPA 8015C
Pentachlorophenol	**13**	mg/kg	1.4	4.5	2		01/09/2014 14:00	01/13/2014 19:47	RPN	EPA 8270D

CT LAB Sample#: 417144 Sample Description: SB-A-24-27 FE PERM 23 Sampled: 01/06/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**77.4**	%	0.1	0.1	1			01/21/2014 08:50	BMS	EPA 8000C
Organic Results										
Diesel Range Organics	**7200**	mg/kg	460	1500	10		01/09/2014 14:00	01/23/2014 20:28	JJY	EPA 8015C
Pentachlorophenol	**4.8**	mg/kg	1.2	4.1	2		01/09/2014 14:00	01/13/2014 20:10	RPN	EPA 8270D

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Notes: * Indicates Value in between the LOD (limit of detection) and the LOQ (limit of quantitation).

All samples were received intact and properly preserved unless otherwise noted. The results reported relate only to the samples tested. This report shall not be reproduced, except in full, without written approval of this laboratory. The Chain of Custody is attached.

Submitted by: Pat M. Letterer
Project Manager
608-356-2760

QC Qualifiers

Code	Description
B	Analyte detected in the associated Method Blank.
C	Toxicity present in BOD sample.
D	Diluted Out.
E	Safe, No Total Coliform detected.
F	Unsafe, Total Coliform detected, no E. Coli detected.
G	Unsafe, Total Coliform detected and E. Coli detected.
H	Holding time exceeded.
J	Estimated value.
L	Significant peaks were detected outside the chromatographic window.
M	Matrix spike and/or Matrix Spike Duplicate recovery outside acceptance limits.
N	Insufficient BOD oxygen depletion.
O	Complete BOD oxygen depletion.
P	Concentration of analyte differs more than 40% between primary and confirmation analysis.
Q	Laboratory Control Sample outside acceptance limits.
R	See Narrative at end of report.
S	Surrogate standard recovery outside acceptance limits due to apparent matrix effects.
T	Sample received with improper preservation or temperature.
U	Analyte concentration was below detection limit.
V	Raised Quantitation or Reporting Limit due to limited sample amount or dilution for matrix background interference.
W	Sample amount received was below program minimum.
X	Analyte exceeded calibration range.
Y	Replicate/Duplicate precision outside acceptance limits.
Z	Specified calibration criteria was not met.

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Illinois NELAP ID# 002413
Kansas NELAP ID# E-10368
Kentucky ID# 0023
Pennsylvania NELAP ID# 68-04201
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Wisconsin (DATCP) Bacteriology ID# 105-289
DoD-ELAP A2LA Cert # 3317.013
Alaska ID # UST-099
Louisiana ID # 115843
Virginia ID# 460203
ISO/IEC 17025-2005 A2LA Cert # 3317.01
GA EPD Stipulation ID 115843, Expires Annually

Ursus

Chain of Custody

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Company Name:	Ursus Remediation Testing & Technolgoes	Send Samples to:	Laboratory Use Only
Project Contact:	Andy Wenzel — Address: 200 E Lincoln St	Ursus Remediation Testing & Tech	Ice Present (Yes) No
City/State/Zip	Mount Horeb, WI 53572 — Telephone: 608-437-7413	200 E Lincoln Street	Sample Conditions
Project Name:	AMEC - JH Baxter	Mount Horeb, WI 53572	6.8°C HHK 1/8/14 @1530
Project Number:	NA	PH 608-437-7413	
Project Location:	NA		
Sampled By:	ADW		

Client Sample Collection Method Comments:

Preservation*

Fill in Spaces with Bottles per Test

	Collection Date	Collection Time	Grab/ Comp	Sample ID Description	Filt'd Y/N	**Matrix	DRO	PCP	Total No of Containers	Lab ID #
1	1/6/2014	1:00 PM	Grab	SB-D-30-33 Control	N	S	x	x		417129
2	1/6/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 46 g/kg	N	S	x	x		" 130
3	1/6/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 92 g/kg	N	S	x	x		131
4	1/6/2014	1:00 PM	Grab	SB-D-30-33 H2O2 Pers 46 g/kg	N	S	x	x		132
5	1/6/2014	1:00 PM	Grab	SB-D-30-33 H2O2 Pers 92 g/kg	N	S	x	x		133
6	1/6/2014	1:00 PM	Grab	SB-D-30-33 Fe Pers 46 g/kg	N	S	x	x		134
7	1/6/2014	1:00 PM	Grab	SB-D-30-33 Fe Pers 92 g/kg	N	S	x	x		135
8	1/6/2014	1:00 PM	Grab	SB-D-30-33 Perm 23 g/kg	N	S	x	x		136
9	1/6/2014	1:00 PM	Grab	SB-A-24-27 Control	N	S	x	x		137
10	1/6/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 87.5 g/kg	N	S	x	x		138
11	1/6/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 175 g/kg	N	S	x	x		139

Folder #: 102095
Company: URSUS REMEDIATION
Project: AMEC-JH BAXTER
Logged By: HHK PM: PM

Relinquished By: Andrew Wenzel	Date/Time 1/8/14 3:30 PM	Relinquished By:	Date/Time
Received by:	Date/Time	Received by: HHK 1/8/14 @ 1533	Date/Time

*Preservation
A=None
B=HCL
C=H2SO4
D=HNO3
E=NaOH
F=Methanol
O=Other

**Matrix
S-Soil
Slg-Sludge
I-Indst Waste
GW-Groundwater
SW-Surface Water
WW-Wastewater

2 of 2 102095

Company Name:	Ursus Remediation Testing & Technolgoes
Project Contact:	Andy Wenzel
City/State/Zip	Mount Horeb, WI 53572
Project Name:	AMEC - JH Baxter
Project Number:	NA
Project Location:	NA
Sampled By:	ADW

Address: 200 E Lincoln St
Telephone: 608-437-7413

Send Samples to:
Ursus Remediation Testing & Tech
200 E Lincoln Street
Mount Horeb, WI 53572
PH 608-437-7413

Laboratory Use Only
Ice Present Yes No
Sample Conditions

Client Sample Collection Method Comments:

Preservation*

	Collection Date	Collection Time	Grab/ Comp	Sample ID Description	Filt'd Y/N	**Matrix:	DRO	PCP										Total No of Containers	Lab ID #
12	1/6/2014	1:00 PM	Grab	SB-A-24-27 H2O2 Pers 87.5 g/kg	N	S	x	x											417140
13	1/6/2014	1:00 PM	Grab	SB-A-24-27 H2O2 Pers 175 g/kg	N	S	x	x											141
14	1/6/2014	1:00 PM	Grab	SB-A-24-27 Fe Pers 87.5 g/kg	N	S	x	x											142
15	1/6/2014	1:00 PM	Grab	SB-A-24-27 Fe Pers 175 g/kg	N	S	x	x											143
16	1/6/2014	1:00 PM	Grab	SB-A-24-27 Perm 23 g/kg	N	S	x	x											144

Fill in Spaces with Bottles per Test

*Preservation
A=None
B=HCL
C=H2SO4
D=HNO3
E=NaOH
F=Methanol
O=Other

Relinquished By:	Date/Time	Relinquished By:	Date/Time
Received by:	Date/Time	Received by:	Date/Time

**Matrix
S-Soil
Slg-Sludge
I-Indst Waste
GW-Groundwater
SW-Surface Water
WW-Wastewater

200 E Lincoln Street
Mount Horeb, WI 53572
(608) 437-7413

APPENDIX B – CT Laboratory Analytical Report
Round 1 Data Set 2

CT LABORATORIES
delivering more than data from your environmental analyses

URSUS REMEDIATION TESTING & TE
Project Name: AMEC - JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 102830
Page 3 of 8

CT LAB Sample#: 427288 Sample Description: SB-D-30-33 H2O2 PERS 115 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Organic Results										
Diesel Range Organics	**5200**	mg/kg	520	1700	10		3/5/2014 11:00	3/10/2014 19:06	JJY	EPA 8015C
Pentachlorophenol	**27**	mg/kg	14 *	46	20		3/5/2014 08:30	3/7/2014 18:10	RPN	EPA 8270D

CT LAB Sample#: 427289 Sample Description: SB-D-30-33 FE PERS 69 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**68.5**	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	**8200**	mg/kg	520	1700	10		3/5/2014 11:00	3/10/2014 19:33	JJY	EPA 8015C
Pentachlorophenol	**63**	mg/kg	7.0	23	10		3/5/2014 08:30	3/7/2014 18:28	RPN	EPA 8270D

CT LAB Sample#: 427290 Sample Description: SB-D-30-33 FE PERS 115 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**69.3**	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	**5000**	mg/kg	520	1700	10		3/5/2014 11:00	3/11/2014 14:41	JJY	EPA 8015C
Pentachlorophenol	**30**	mg/kg	3.4	11	5		3/5/2014 08:30	3/7/2014 18:45	RPN	EPA 8270D

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
delivering more than data from your environmental analyses

URSUS REMEDIATION TESTING & TE
Project Name: AMEC - JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 102830
Page 4 of 8

CT LAB Sample#: 427291 Sample Description: SB-D-30-33 PERM 69 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	65.0	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	6400	mg/kg	550	1800	10		3/5/2014 11:00	3/11/2014 15:08	JJY	EPA 8015C
Pentachlorophenol	31	mg/kg	7.4	25	10		3/5/2014 08:30	3/7/2014 19:03	RPN	EPA 8270D

CT LAB Sample#: 427292 Sample Description: SB-A-24-27 CONTROL Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	74.2	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	3400	mg/kg	480	1600	10		3/5/2014 11:00	3/11/2014 15:35	JJY	EPA 8015C
Pentachlorophenol	31	mg/kg	6.4	21	10		3/5/2014 08:30	3/7/2014 19:21	RPN	EPA 8270D

CT LAB Sample#: 427293 Sample Description: SB-A-24-27 ALK PERS 175 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	62.6	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
delivering more than data from your environmental analyses

URSUS REMEDIATION TESTING & TE
Project Name: AMEC - JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 102830
Page 5 of 8

CT LAB Sample#: 427293 Sample Description: SB-A-24-27 ALK PERS 175 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Diesel Range Organics	3400	mg/kg	570	1900	10		3/5/2014 11:00	3/11/2014 16:01	JJY	EPA 8015C
Qualifiers applying to all Analytes of Method EPA 8270D: V										
Pentachlorophenol	<3.8	mg/kg	3.8	13	5		3/5/2014 08:30	3/10/2014 17:46	RPN	EPA 8270D

CT LAB Sample#: 427294 Sample Description: SB-A-24-27 ALK PERS 350 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	50.4	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	4700	mg/kg	700	2300	10		3/5/2014 11:00	3/11/2014 16:55	JJY	EPA 8015C
Qualifiers applying to all Analytes of Method EPA 8270D: V										
Pentachlorophenol	<4.7	mg/kg	4.7	16	5		3/5/2014 08:30	3/10/2014 18:06	RPN	EPA 8270D

CT LAB Sample#: 427295 Sample Description: SB-A-24-27 H2O2 PERS 175 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	74.0	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	2700	mg/kg	480	1600	10		3/5/2014 11:00	3/11/2014 17:22	JJY	EPA 8015C

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
delivering more than data from your environmental analyses

URSUS REMEDIATION TESTING & TE
Project Name: AMEC - JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 102830
Page 6 of 8

CT LAB Sample#: 427295 Sample Description: SB-A-24-27 H2O2 PERS 175 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Pentachlorophenol	7.3	mg/kg	3.2 *	11	5		3/5/2014 08:30	3/7/2014 20:14	RPN	EPA 8270D

CT LAB Sample#: 427296 Sample Description: SB-A-24-27 H2O2 PERS 350 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	70.2	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	3100	mg/kg	250	830	5		3/5/2014 11:00	3/11/2014 17:48	JJY	EPA 8015C
Pentachlorophenol	7.4	mg/kg	1.4	4.6	2		3/5/2014 08:30	3/7/2014 20:32	RPN	EPA 8270D

CT LAB Sample#: 427297 Sample Description: SB-A-24-27 FE PERS 175 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	73.7	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	2600	mg/kg	490	1600	10		3/5/2014 11:00	3/11/2014 18:15	JJY	EPA 8015C
Pentachlorophenol	8.6	mg/kg	1.3	4.3	2		3/5/2014 08:30	3/7/2014 20:49	RPN	EPA 8270D

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
delivering more than data from your environmental analyses

URSUS REMEDIATION TESTING & TE
Project Name: AMEC - JH BAXTER
Project #:
Project Phase:

Contract #: 2069
Folder #: 102830
Page 7 of 8

CT LAB Sample#: 427298 Sample Description: SB-A-24-27 FE PERS 350 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	72.3	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	2800	mg/kg	250	810	5		3/5/2014 11:00	3/11/2014 18:42	JJY	EPA 8015C
Pentachlorophenol	11	mg/kg	1.3	4.4	2		3/5/2014 08:30	3/7/2014 21:07	RPN	EPA 8270D

CT LAB Sample#: 427299 Sample Description: SB-A-24-27 PERM 87.6 Sampled: 2/28/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	73.2	%	0.1	0.1	1			3/3/2014 10:10	MDS	EPA 8000C
Organic Results										
Diesel Range Organics	2800	mg/kg	490	1600	10		3/5/2014 11:00	3/11/2014 19:09	JJY	EPA 8015C
Qualifiers applying to all Analytes of Method EPA 8270D: V										
Pentachlorophenol	<3.3	mg/kg	3.3	11	5		3/5/2014 08:30	3/10/2014 18:23	RPN	EPA 8270D

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
delivering more than data from your environmental analyses

URSUS REMEDIATION TESTING & TE
Project Name: AMEC - JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 102830

Notes: * Indicates Value in between the LOD (limit of detection) and the LOQ (limit of quantitation).

All samples were received intact and properly preserved unless otherwise noted. The results reported relate only to the samples tested. This report shall not be reproduced, except in full, without written approval of this laboratory. The Chain of Custody is attached.

Submitted by: Pat M. Letterer
Project Manager
608-356-2760

QC Qualifiers

Code	Description
B	Analyte detected in the associated Method Blank.
C	Toxicity present in BOD sample.
D	Diluted Out.
E	Safe, No Total Coliform detected.
F	Unsafe, Total Coliform detected, no E. Coli detected.
G	Unsafe, Total Coliform detected and E. Coli detected.
H	Holding time exceeded.
J	Estimated value.
L	Significant peaks were detected outside the chromatographic window.
M	Matrix spike and/or Matrix Spike Duplicate recovery outside acceptance limits.
N	Insufficient BOD oxygen depletion.
O	Complete BOD oxygen depletion.
P	Concentration of analyte differs more than 40% between primary and confirmation analysis.
Q	Laboratory Control Sample outside acceptance limits.
R	See Narrative at end of report.
S	Surrogate standard recovery outside acceptance limits due to apparent matrix effects.
T	Sample received with improper preservation or temperature.
U	Analyte concentration was below detection limit.
V	Raised Quantitation or Reporting Limit due to limited sample amount or dilution for matrix background interference.
W	Sample amount received was below program minimum.
X	Analyte exceeded calibration range.
Y	Replicate/Duplicate precision outside acceptance limits.
Z	Specified calibration criteria was not met.

Current CT Laboratories Certifications
Illinois NELAP ID# 002413
Kansas NELAP ID# E-10368
Kentucky ID# 0023
Pennsylvania NELAP ID# 68-04201
New Jersey NELAP ID# WI001
North Carolina ID# 674
Wisconsin (WDNR) Chemistry ID# 157066030
Wisconsin (DATCP) Bacteriology ID# 105-289
DoD-ELAP A2LA Cert # 3317.013
Alaska ID # UST-099
Louisiana ID # 115843
Virginia ID# 460203
ISO/IEC 17025-2005 A2LA Cert # 3317.01
GA EPD Stipulation ID 115843, Expires Annually

Ursus Remediation Testing & Technologies

Chain of Custody

Page 1 of 2

Company Name:	Ursus Remediation Testing & Technolgoes	Send Samples to:	Laboratory Use Only
Project Contact:	Andy Wenzel; Address: 200 E Lincoln St	Ursus Remediation Testing & Tech	Ice Present (Yes) No
City/State/Zip:	Mount Horeb, WI 53572; Telephone: 608-437-7413	200 E Lincoln Street	Sample Conditions
Project Name:	AMEC - JH Baxter	Mount Horeb, WI 53572	15.9
Project Number:	NA	PH 608-437-7413	
Project Location:	NA		tkr 2/28/14 3:30
Sampled By:	ADW	Folder #. 102830	

Company: URSUS REMEDIATION
Project: AMEC - JH BAXTER
Logged By: TKR PM: PM

Client Sample Collection Method Comments:

Preservation*: A=None, B=HCL, C=H2SO4, D=HNO3, E=NaOH, F=Methanol, O=Other

	Date	Time	Grab/Comp	Sample ID Description	Filt'd Y/N	**Matrix	DRO	PCP	Total No of Containers	Lab ID #
1	2/28/2014	1:00 PM	Grab	SB-D-30-33 Control	N	S	x	x		427284
2	2/28/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 69 g/kg	N	S	x	x		427285
3	2/28/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 115 g/kg	N	S	x	x		427286
4	2/28/2014	1:00 PM	Grab	SB-D-30-33 H2O2 Pers 69 g/kg	N	S	x	x		427287
5	2/28/2014	1:00 PM	Grab	SB-D-30-33 H2O2 Pers 115 g/kg	N	S	x	x		427288
6	2/28/2014	1:00 PM	Grab	SB-D-30-33 Fe Pers 69 g/kg	N	S	x	x		427289
7	2/28/2014	1:00 PM	Grab	SB-D-30-33 Fe Pers 115 g/kg	N	S	x	x		427290
8	2/28/2014	1:00 PM	Grab	SB-D-30-33 Perm 69 g/kg	N	S	x	x		427291
9	2/28/2014	1:00 PM	Grab	SB-A-24-27 Control	N	S	x	x		427292
10	2/28/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 175 g/kg	N	S	x	x		427293
11	2/28/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 350 g/kg	N	S	x	x		427294

Fill in Spaces with Bottles per Test

Relinquished By:	Date/Time	Relinquished By:	Date/Time
Andrew Wenzel	2/28/14 1507		
Received by:	Date/Time	Received by:	Date/Time
		tkr	2/28/14 4:03

**Matrix: S-Soil, Slg-Sludge, I-Indst Waste, GW-Groundwater, SW-Surface Water, WW-Wastewater

182

Company Name:	Ursus Remediation Testing & Technolgpes	Send Samples to:	Laboratory Use Only
Project Contact:	Andy Wenzel — Address: 200 E Lincoln St	Ursus Remediation Testing & Tech	Ice Present Yes No
City/State/Zip:	Mount Horeb, WI 53572 — Telephone: 608-437-7413	200 E Lincoln Street	Sample Conditions
Project Name:	AMEC - JH Baxter	Mount Horeb, WI 53572	
Project Number:	NA	PH 608-437-7413	
Project Location:	NA		
Sampled By:	ADW		

Client Sample Collection Method Comments:

Preservation*

	Collection Date	Collection Time	Grab/ Comp	Sample ID Description	Filt'd Y/N	**Matrix	DRO	PCP	Total No of Containers	Lab ID #
12	2/28/2014	1:00 PM	Grab	SB-A-24-27 H2O2 Pers 175 g/kg	N	S	x	x		427295
13	2/28/2014	1:00 PM	Grab	SB-A-24-27 H2O2 Pers 350 g/kg	N	S	x	x		427296
14	2/28/2014	1:00 PM	Grab	SB-A-24-27 Fe Pers 175 g/kg	N	S	x	x		427297
15	2/28/2014	1:00 PM	Grab	SB-A-24-27 Fe Pers 350 g/kg	N	S	x	x		427298
16	2/28/2014	1:00 PM	Grab	SB-A-24-27 Perm 87.6 g/kg	N	S	x	x		427299

Fill in Spaces with Bottles per Test

*Preservation: A=None, B=HCL, C=H2SO4, D=HNO3, E=NaOH, F=Methanol, O=Other

Relinquished By:	Date/Time	Relinquished By:	Date/Time
[signature]	2/28/14 1552		
Received by:	Date/Time	Received by:	Date/Time
		fkr	2/28/14 4:03

**Matrix: S-Soil, Slg-Sludge, I-Indst Waste, GW-Groundwater, SW-Surface Water, WW-Wastewater

Ursus Remediation Testing & Technologies LLC
200 E Lincoln Street
Mount Horeb, WI 53572
(608) 437-7413

APPENDIX C – CT Laboratory Analytical Report
Round 2 Data Set 1

Ursus
Remediation Testing & Technologies LLC

200 E Lincoln Street
Mount Horeb, WI 53572
(608) 437-7413

CT LABORATORIES
delivering more than data from your environmental analyses

CT Laboratories LLC • 1230 Lange Ct • Baraboo, WI 53913
608-356-2760 • www.ctlaboratories.com

ANALYTICAL REPORT

URSUS REMEDIATION TESTING & TE
ANDREW WENZEL
1412 MANOR DRIVE
MOUNT HOREB, WI 53572

Project Name: AMEC-JH BAXTER
Project Phase:
Contract #: 2089
Project #:
Folder #: 106184
Purchase Order #:

Arrival Temperature: See COC
Report Date: 09/09/2014
Date Received: 08/14/2014
Reprint Date: 09/09/2014

CT LAB Sample#: 488374 Sample Description: SB-D-30-33 CONTROL Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**70.5**	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	**12000**	mg/kg	400	1400	10	M	08/14/2014 13:30	08/18/2014 11:17	SRT	EPA 8015C
Pentachlorophenol	**18**	mg/kg	1.2	3.7	20	M	08/14/2014 13:30	08/21/2014 11:47	RPN	EPA 8270D

CT LAB Sample#: 488375 Sample Description: SB-D-30-33 CONTROL-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**71.4**	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	**22**	mg/kg	1.2	3.7	20		08/14/2014 13:30	08/21/2014 12:07	RPN	EPA 8270D

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
delivering more than data from your environmental analyses

URSUS REMEDIATION TESTING & TE
Project Name: AMEC-JH BAXTER
Project #:
Project Phase:

Contract #: 2069
Folder #: 108184
Page 2 of 8

CT LAB Sample#: 488376 Sample Description: SB-D-30-33 ALK PERS 8G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	73.4	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	14000	mg/kg	380	1300	10		08/14/2014 13:30	08/18/2014 12:33	SRT	EPA 8015C
Pentachlorophenol	26	mg/kg	0.28	0.89	5		08/14/2014 13:30	08/21/2014 12:27	RPN	EPA 8270D

CT LAB Sample#: 488377 Sample Description: SB-D-30-33 ALK PERS 8G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	73.8	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	26	mg/kg	0.29	0.90	5		08/14/2014 13:30	08/21/2014 12:47	RPN	EPA 8270D

CT LAB Sample#: 488378 Sample Description: SB-D-30-33 ALK PERS 16G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	73.6	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	14000	mg/kg	380	1300	10		08/14/2014 13:30	08/18/2014 12:58	SRT	EPA 8015C

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
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URSUS REMEDIATION TESTING & TE
Project Name: AMEC-JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 106184
Page 3 of 8

CT LAB Sample#: 488378 Sample Description: SB-D-30-33 ALK PERS 16G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Pentachlorophenol	20	mg/kg	0.28	0.89	5		08/14/2014 13:30	08/21/2014 13:07	RPN	EPA 8270D

CT LAB Sample#: 488379 Sample Description: SB-D-30-33 ALK PERS 16G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	74.0	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	6.2	mg/kg	0.28	0.89	5		08/14/2014 13:30	08/21/2014 13:26	RPN	EPA 8270D

CT LAB Sample#: 488380 Sample Description: SB-D-30-33 ALK PERS 23G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	75.4	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	15000	mg/kg	370	1300	10		08/14/2014 13:30	08/18/2014 13:23	SRT	EPA 8015C
Pentachlorophenol	9.0	mg/kg	0.28	0.88	5		08/14/2014 13:30	08/21/2014 13:46	RPN	EPA 8270D

CT LAB Sample#: 488381 Sample Description: SB-D-30-33 ALK PERS 23G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method

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URSUS REMEDIATION TESTING & TE
Project Name: AMEC-JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 108184
Page 4 of 8

CT LAB Sample#: 488381 Sample Description: SB-D-30-33 ALK PERS 23G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**75.9**	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	**6.3**	mg/kg	0.28	0.87	5		08/14/2014 13:30	08/21/2014 14:06	RPN	EPA 8270D

CT LAB Sample#: 488382 Sample Description: SB-A-24-27 CONTROL Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**80.1**	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	**10000**	mg/kg	350	1200	10		08/14/2014 13:30	08/18/2014 13:48	SRT	EPA 8015C
Pentachlorophenol	**19**	mg/kg	1.0	3.3	20		08/14/2014 13:30	08/21/2014 14:26	RPN	EPA 8270D

CT LAB Sample#: 488383 Sample Description: SB-A-24-27 CONTROL-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	**80.7**	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	**9.9**	mg/kg	1.0	3.2	20		08/14/2014 13:30	08/21/2014 14:46	RPN	EPA 8270D

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URSUS REMEDIATION TESTING & TE
Project Name: AMEC-JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 108184
Page 5 of 8

CT LAB Sample#: 488384 Sample Description: SB-A-24-27 ALK PERS 8G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	81.1	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	9800	mg/kg	340	1200	10		08/14/2014 13:30	08/18/2014 14:14	SRT	EPA 8015C
Pentachlorophenol	7.4	mg/kg	0.26	0.81	5		08/14/2014 13:30	08/21/2014 15:06	RPN	EPA 8270D

CT LAB Sample#: 488385 Sample Description: SB-A-24-27 ALK PERS 8G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	81.0	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	7.5	mg/kg	0.26	0.81	5		08/14/2014 13:30	08/21/2014 15:26	RPN	EPA 8270D

CT LAB Sample#: 488386 Sample Description: SB-A-24-27 ALK PERS 16G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	81.0	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	8900	mg/kg	340	1200	10		08/14/2014 13:30	08/18/2014 15:30	SRT	EPA 8015C

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URSUS REMEDIATION TESTING & TE
Project Name: AMEC-JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 106184
Page 6 of 8

CT LAB Sample#: 488386 Sample Description: SB-A-24-27 ALK PERS 16G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Pentachlorophenol	6.2	mg/kg	0.26	0.80	5		08/14/2014 13:30	08/21/2014 15:46	RPN	EPA 8270D

CT LAB Sample#: 488387 Sample Description: SB-A-24-27 ALK PERS 16G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	79.5	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	8.2	mg/kg	0.26	0.83	5		08/14/2014 13:30	08/21/2014 16:32	RPN	EPA 8270D

CT LAB Sample#: 488388 Sample Description: SB-A-24-27 ALK PERS 23G/KG Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	81.1	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Diesel Range Organics	11000	mg/kg	350	1200	10		08/14/2014 13:30	08/18/2014 15:55	SRT	EPA 8015C
Pentachlorophenol	8.4	mg/kg	0.26	0.82	5		08/14/2014 13:30	08/21/2014 16:52	RPN	EPA 8270D

CT LAB Sample#: 488389 Sample Description: SB-A-24-27 ALK PERS 23G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method

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URSUS REMEDIATION TESTING & TE
Project Name: AMEC-JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 106184
Page 7 of 8

CT LAB Sample#: 488389 Sample Description: SB-A-24-27 ALK PERS 23G/KG-DUP Sampled: 08/14/2014 1300

Analyte	Result	Units	LOD	LOQ	Dilution	Qualifier	Prep Date/Time	Analysis Date/Time	Analyst	Method
Inorganic Results										
Solids, Percent	80.3	%	0.1	0.1	1			08/14/2014 14:50	ABS	EPA 8000C
Organic Results										
Pentachlorophenol	7.7	mg/kg	0.26	0.82	5		08/14/2014 13:30	08/21/2014 17:12	RPN	EPA 8270D

Unless specifically stated to the contrary, soil/sediment/sludge sample results reported on a Dry Weight Basis

CT LABORATORIES
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URSUS REMEDIATION TESTING & TE
Project Name: AMEC-JH BAXTER
Project #:
Project Phase:

Contract #: 2089
Folder #: 108184
Page 8 of 8

Notes: * Indicates Value in between the LOD (limit of detection) and the LOQ (limit of quantitation).

All samples were received intact and properly preserved unless otherwise noted. The results reported relate only to the samples tested. This report shall not be reproduced, except in full, without written approval of this laboratory. The Chain of Custody is attached.

Submitted by: Pat M. Letterer
Project Manager
608-356-2760

QC Qualifiers

Code	Description
B	Analyte detected in the associated Method Blank.
C	Toxicity present in BOD sample.
D	Diluted Out.
E	Safe, No Total Coliform detected.
F	Unsafe, Total Coliform detected, no E. Coli detected.
G	Unsafe, Total Coliform detected and E. Coli detected.
H	Holding time exceeded.
J	Estimated value.
L	Significant peaks were detected outside the chromatographic window.
M	Matrix spike and/or Matrix Spike Duplicate recovery outside acceptance limits.
N	Insufficient BOD oxygen depletion.
O	Complete BOD oxygen depletion.
P	Concentration of analyte differs more than 40% between primary and confirmation analysis.
Q	Laboratory Control Sample outside acceptance limits.
R	See Narrative at end of report.
S	Surrogate standard recovery outside acceptance limits due to apparent matrix effects.
T	Sample received with improper preservation or temperature.
U	Analyte concentration was below detection limit.
V	Raised Quantitation or Reporting Limit due to limited sample amount or dilution for matrix background interference.
W	Sample amount received was below program minimum.
X	Analyte exceeded calibration range.
Y	Replicate/Duplicate precision outside acceptance limits.
Z	Specified calibration criteria was not met.

Current CT Laboratories Certifications
Illinois NELAP ID# 002413
Kansas NELAP ID# E-10368
Kentucky ID# 0023
Pennsylvania NELAP ID# 68-04201
New Jersey NELAP ID# WI001
North Carolina ID# 674
Wisconsin (WDNR) Chemistry ID# 157066030
Wisconsin (DATCP) Bacteriology ID# 105-289
DoD-ELAP A2LA Cert # 3317.013
Alaska ID # UST-099
Louisiana ID # 115843
Virginia ID# 460203
ISO/IEC 17025-2005 A2LA Cert # 3317.01
GA EPD Stipulation ID 115843, Expires Annually

Ursus

Chain of Custody

Page 1 of 2

Company Name:	Ursus Remediation Testing & Technolgoes	Send Samples to:	Laboratory Use Only
Project Contact:	Andy Wenzel; Address: 200 E Lincoln St	Ursus Remediation Testing & Tech	Ice Present (Yes) No
City/State/Zip:	Mount Horeb, WI 53572; Telephone: 608-437-7413	200 E Lincoln Street	Sample Conditions 7.3° #3
Project Name:	AMEC - JH Baxter	Mount Horeb, WI 53572	TKR 8/14/14 1045
Project Number:	NA	PH 608-437-7413	
Project Location:	NA		
Sampled By:	ADW		

Client Sample Collection Method Comments:

Folder #: 106184
Company: URSUS REMEDIATION
Project: AMEC-JH BAXTER
Logged By: TKR PM: PM

Preservation*

Collection Date	Collection Time	Grab/ Comp	Sample ID Description	Filt'd Y/N	**Matrix	DRO	PCP									Total No of Containers	Lab ID #
8/14/2014	1:00 PM	Grab	SB-D-30-33 Control	N	S	x	x										488374
8/14/2014	1:00 PM	Grab	SB-D-30-33 Control - DUP	N	S		x										488375
8/14/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 8 g/kg	N	S	x	x										488376
8/14/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 8 g/kg - DUP	N	S		x										488377
8/14/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 16 g/kg	N	S	x	x										488378
8/14/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 16 g/kg - DUP	N	S		x										488379
8/14/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 23 g/kg	N	S	x	x										488380
8/14/2014	1:00 PM	Grab	SB-D-30-33 Alk Pers 23 g/kg - DUP	N	S		x										488381
8/14/2014	1:00 PM	Grab	SB-A-24-27 Control	N	S	x	x										488382
8/14/2014	1:00 PM	Grab	SB-A-24-27 Control - DUP	N	S		x										488383
8/14/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 8 g/kg	N	S	x	x										488384

Fill in Spaces with Bottles per Test

Relinquished By:	Date/Time	Relinquished By:	Date/Time
Andy Wenzel	8/14/14 1030		
Received by:	**Date/Time**	**Received by:**	**Date/Time**
		TKR	8/14/14 1317

*Preservation: A=None, B=HCL, C=H2SO4, D=HNO3, E=NaOH, F=Methanol, O=Other

**Matrix: S-Soil, Slg-Sludge, I-Indst Waste, GW-Groundwater, SW-Surface Water, WW-Wastewater

2 of 2

Company Name:	Ursus Remediation Testing & Technolgoes		
Project Contact:	Andy Wenzel	Address:	200 E Lincoln St
City/State/Zip	Mount Horeb, WI 53572	Telephone:	608-437-7413
Project Name:	AMEC - JH Baxter		
Project Number:	NA		
Project Location:	NA		
Sampled By:	ADW		

Send Samples to:
Ursus Remediation Testing & Tech
200 E Lincoln Street
Mount Horeb, WI 53572
PH 608-437-7413

Laboratory Use Only
Ice Present Yes No
Sample Conditions 7.3°#3
TKR 8/14/14 1045

Client Sample Collection Method Comments:

Preservation*

Collection Date	Collection Time	Grab/ Comp	Sample ID Description	Filt'd Y/N	**Matrix	DRO	PCP	Total No of Containers	Lab ID #
8/14/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 8 g/kg - DUP	N	S		x		488385
8/14/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 16 g/kg	N	S	x	x		488386
8/14/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 16 g/kg - DUP	N	S		x		488387
8/14/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 23 g/kg	N	S	x	x		488388
8/14/2014	1:00 PM	Grab	SB-A-24-27 Alk Pers 23 g/kg - DUP	N	S		x		488389

Fill in Spaces with Bottles per Test

*Preservation
A=None
B=HCL
C=H2SO4
D=HNO3
E=NaOH
F=Methanol
O=Other

Relinquished By: [signature]	Date/Time 8/14/14 1030	Relinquished By:	Date/Time
Received by:	Date/Time	Received by: [signature]	Date/Time 8/14/14 1317

**Matrix
S-Soil
Slg-Sludge
I-Indst Waste
GW-Groundwater
SW-Surface Water
WW-Wastewater